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A COMPILATION OF SPACECRAFT LOADS DATA
FROM
FOUR TITAN CENTAUR LAUNCH VEHICLE FLIGHTS

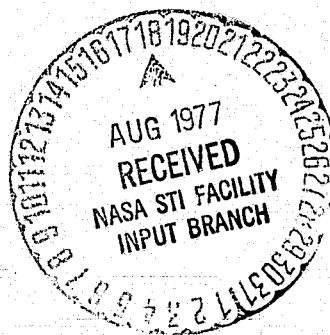
VOLUME III: SHOCK SPECTRA OF TRANSIENTS

Compiled by: George Kachadourian

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SPACECRAFT LOADS DATA FROM FOUR TITAN
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PART 2: SHOCK SPECTRA OF TRANSIENTS
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A COMPILATION OF SPACECRAFT LOADS DATA
FROM
FOUR TITAN CENTAUR LAUNCH VEHICLE FLIGHTS
VOLUME III: SHOCK SPECTRA OF TRANSIENTS

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ABSTRACT

The payloads carried by the first four Titan Centaur Launch Vehicle Flights were, a Viking Spacecraft Dynamic Simulator, the Helios-1 spacecraft and the two Viking Spacecraft. A wealth of dynamic loads data was accumulated by the NASA Viking Project Office from these four flights for application to the Viking Spacecraft. This report contains a compilation of that data and is presented for reference and information. The data has been compiled into the following five Volumes:

- Volume I - Acoustic Data (CR-144944)
- Volume II - Vibration Power Spectral Density Data (CR-144945)
- Volume III - Shock Spectra of Transients (CR-144946)
- Volume IV - Titan Stage I and Centaur Burn Oscillation (CR-144947)
- Volume V - Time History Plots (CR-144948)

VOLUME III, SECTION 2
SHOCK SPECTRA OF TRANSIENT EVENTS
TC-1 LAUNCH
VIKING DYNAMIC SIMULATOR

This section performed and written by
Henry T. Thornton, Jr.
of the
Langley Research Center
Systems Engineering Division

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SHOCK SPECTRA

VIKING DYNAMIC SIMULATOR TEST FLIGHT

Summary:

Included herein are shock spectrum analyses for each of seven acceleration sensors and five strain sensors for each of six events in the flight sequence. The sensors are identified in Table A and their location are shown in Figures 1 & 2. The six events are listed in Table B along with the nominal start times of the data used for the analyses. The analysis results are grouped by event and secondarily by sensor number. Figure 4 is the first event of "liftoff" and "a" through "m" show the individual sensor responses. The titles for each case appear at the top of the page. Amplitude values are in terms of "g" for acceleration (VODS Accel) and "pounds" force for strain (VLCA Strain). The data in Figures 4 through 9 are for a $Q = 10$. The data are also analyzed for a $Q = 20$ for the accelerometers only which are shown as Figures 10 through 12.

Methods of Analysis:

The shock spectrum analysis program is a minor modification of the "SPOCK" program developed at MMC. This program was developed from the method of recursive filtering presented in "Digital Shock Spectrum Analysis by Recursive Filtering", D. W. Lane, S&V Bulletin 33 Part II. For these data, analyses were made at the approximately one-sixth octave points with the upper frequency limit being twice the rated frequency of the particular telemetry channel or 1000 Hz maximum. The data were digitized at a rate of 2000 samples per second (a compromise rate to provide one digitizing pass at the data tape). This provides a limit of 1000 Hz on the three upper frequency TM channels (16, 17 & 18) and a larger number of data points than necessary for the lower frequency channels. For TM channels 14 and below, output filters of twice the IRIG rated frequency range were used in the demodulators. This provides a greater frequency range but with slightly lower signal to noise ratio and some loss of amplitude information above the rated frequency range approximately similar to the loss through a gaussian filter.

Each data channel for each event was modified by subtracting a constant to make it appear as if the starting value were zero. Thus the effect of any steady state level (or DC level) at the onset is eliminated. Without this correction the shock spectrum program would see a step function onset input which would be erroneous. However, any differential or change in steady state at a later time is included.

A nominal start time for each event was selected from time-expanded oscillographic records. A mean value of the data signal was computed for a time period to the nominal start time. A specific start time was then selected where the data signal level was approximately equal to the calculated mean value.

The data value at the specific start time then became the subtracting constant. See Figure 3(a). For the event Forward Bearing Release (FBR) it was necessary for some channels to extend the digitized data by packing zero amplitude levels for an additional one-third of the available data time. This was necessary to allow time to full response at some of the lower frequencies.

A different type of correction was required for the event Stage I shutdown/ Stage II ignition which are immediately adjacent. At the Stage II ignition there occurred a telemetry signal dropout which obscured the true sensor reaction to the ignition transient. The correction applied here was to stop the data just prior to the signal dropout and to regain the data just after the effects of the signal dropout as if there were no time loss between the two data points. This procedure has the effect of introducing a step function in the data in place of the true smoother change. See Figure 3(b). However, each channel was checked to minimize the effect of opposite going motion at the specific time of the step. It is recognized that this procedure might create a more severe case than using a smoother transition. However, highly filtered data on several channels show an initial pulse which appears valid and which is of greater magnitude than the step change magnitude.

TABLE 2.1 VDS MEASUREMENT LIST CENTAUR FM/FM #2 2215.5 MHz

VCO Number	Measurement Number	Description	Zero Load Bias	Full Scale Range
5	CY208-φ	VODS Sprung Mass Z-Axis Accelerometer	20%	10.01 g's
6	CY207-φ	VODS Bus X-Axis Accelerometer	50%	10.00 g's
7	CY206-φ	VODS Bus Y-Axis Accelerometer	50%	9.99 g's
8	CY205-φ	VODS Bus Y-Axis Accelerometer	50%	10.01 g's
9	CY204-φ	VODS Bus Z-Axis Accelerometer	50%	20.00 g's
10	CY203-φ	VODS Bus Z-Axis Accelerometer	50%	19.98 g's
11	CY202-φ	VODS Bus Z-Axis Accelerometer	50%	20.00 g's
12	CY214-S	PFLA Truss Axial Load, Member 202	59.6%	27177 lbs
13	CY213-S	PFLA Truss Axial Load, Member 203	61.0%	27192 lbs
14	CY212-S	PFLA Truss Axial Load, Member 204	61.1%	27157 lbs
15	CY211-S	PFLA Truss Axial Load, Member 205	59.2%	26636 lbs
16	CY210-S	PFLA Truss Axial Load, Member 206	60.1%	27175 lbs
17	CY209-S	PFLA Truss Axial Load, Member 201	61.6%	27319 lbs
18	CY201-φ	Piezoelectric Accelerometer, Z-Axis	50%	40.0 g's

TABLE 2.2

Events and Nominal Start Times

Launch: 42 days 13 hours 48 min. 1.55 sec ±

<u>Event</u>	<u>Nominal Start Times for Analysis</u>	
Liftoff	48 min	1.550 sec
FBR	49	41.483
Stage I ignition	49	56.830
Stage I shutdown/ Stage II ignition	52 (52)	24.537 (26.450)
Jettison Shroud	52	35.312
Stage II shutdown	55	50.500 ¹

1) Actual start of event is close to 50.83 sec.

TABLE 2.3

List of one-sixth octave frequencies used
for analysis and plotting.

<u>5</u> ,	5.6,	6.3,	7.1,	8,	9,	<u>10</u>
11.5,	12.5,	14	,	16,	18,	<u>20</u>
22.5,	25	,	28.5,	32,	36,	<u>40</u>
45	,	50	,	56	,	63, 71, <u>80</u>
90	,	100	,	115	,	125, 140, <u>160</u>
180	,	200	,	225	,	250, 285, <u>320</u>
360	,	400	,	450	,	500, 560, <u>630</u>
710	,	800	,	900	,	1000

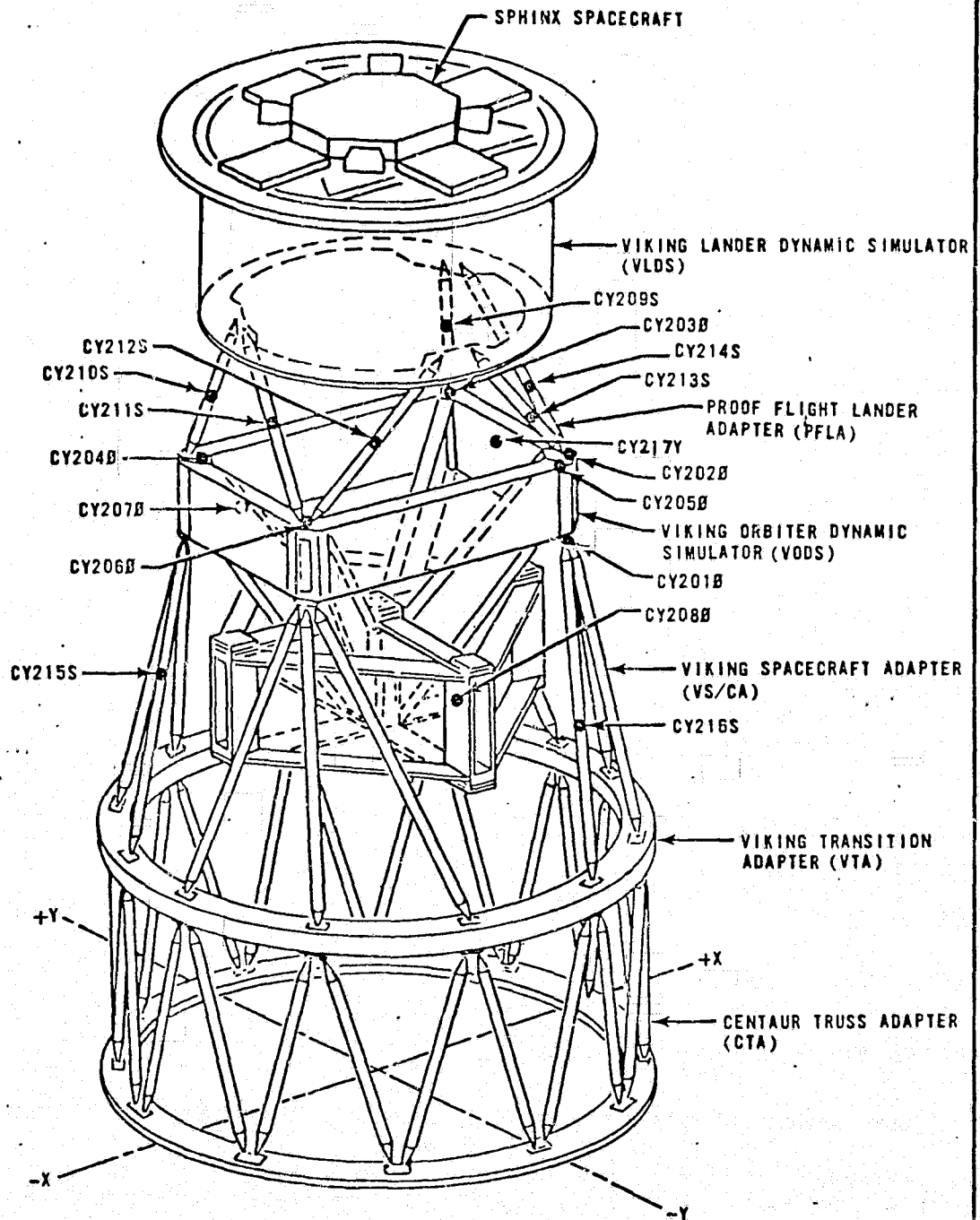


Figure 2.1 Viking Dynamic Simulator Instrumentation

VIKING DYNAMIC SIMULATOR

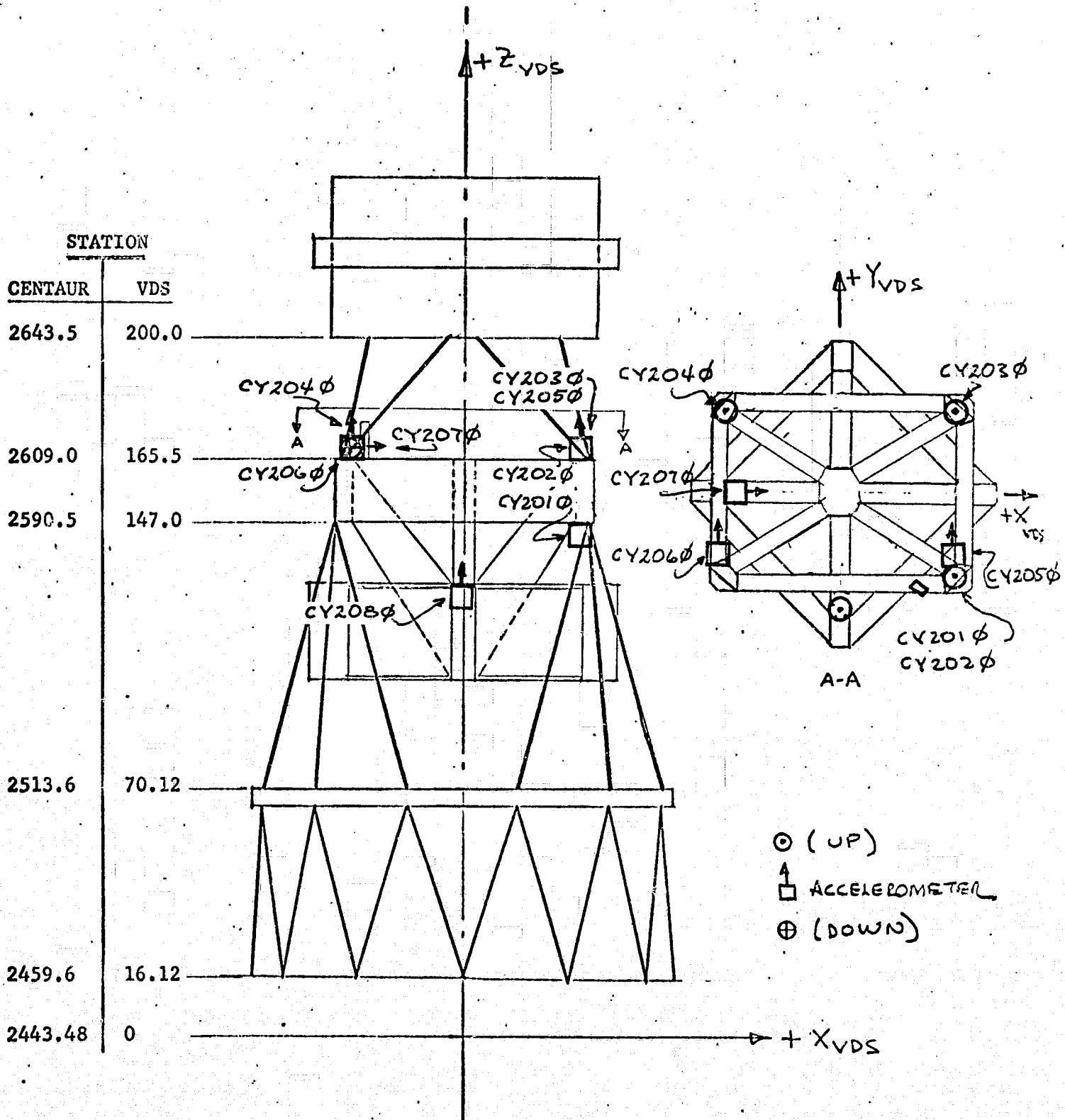
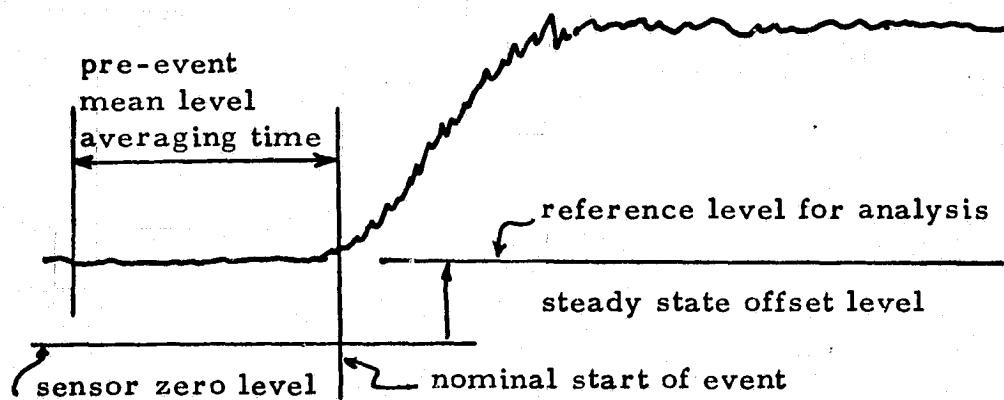
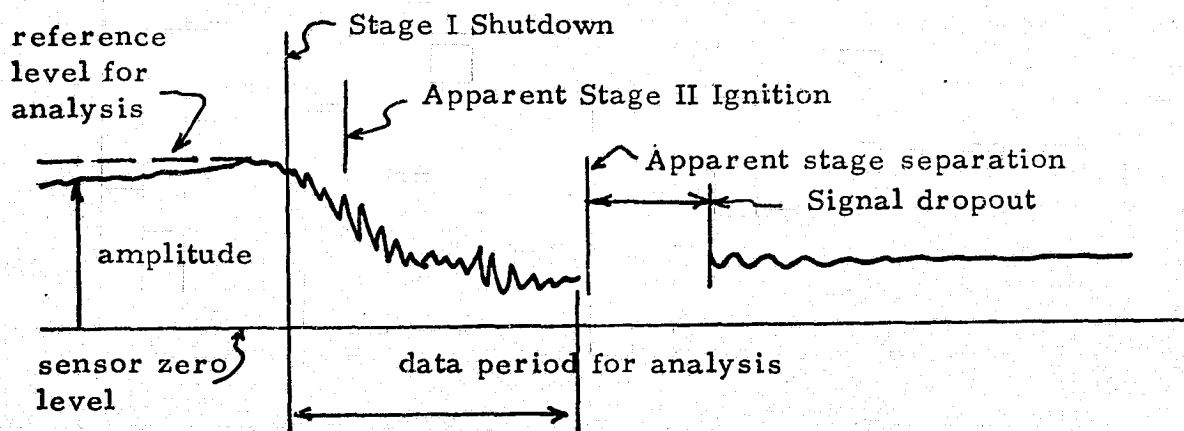


Figure 2.2 - VDS Sensor Locations



a.) Input Data Correction for Sensor Amplitude Offsets



b.) Input Data Correction for Stage I Shutdown

Figure 2.3 Input Data Corrections

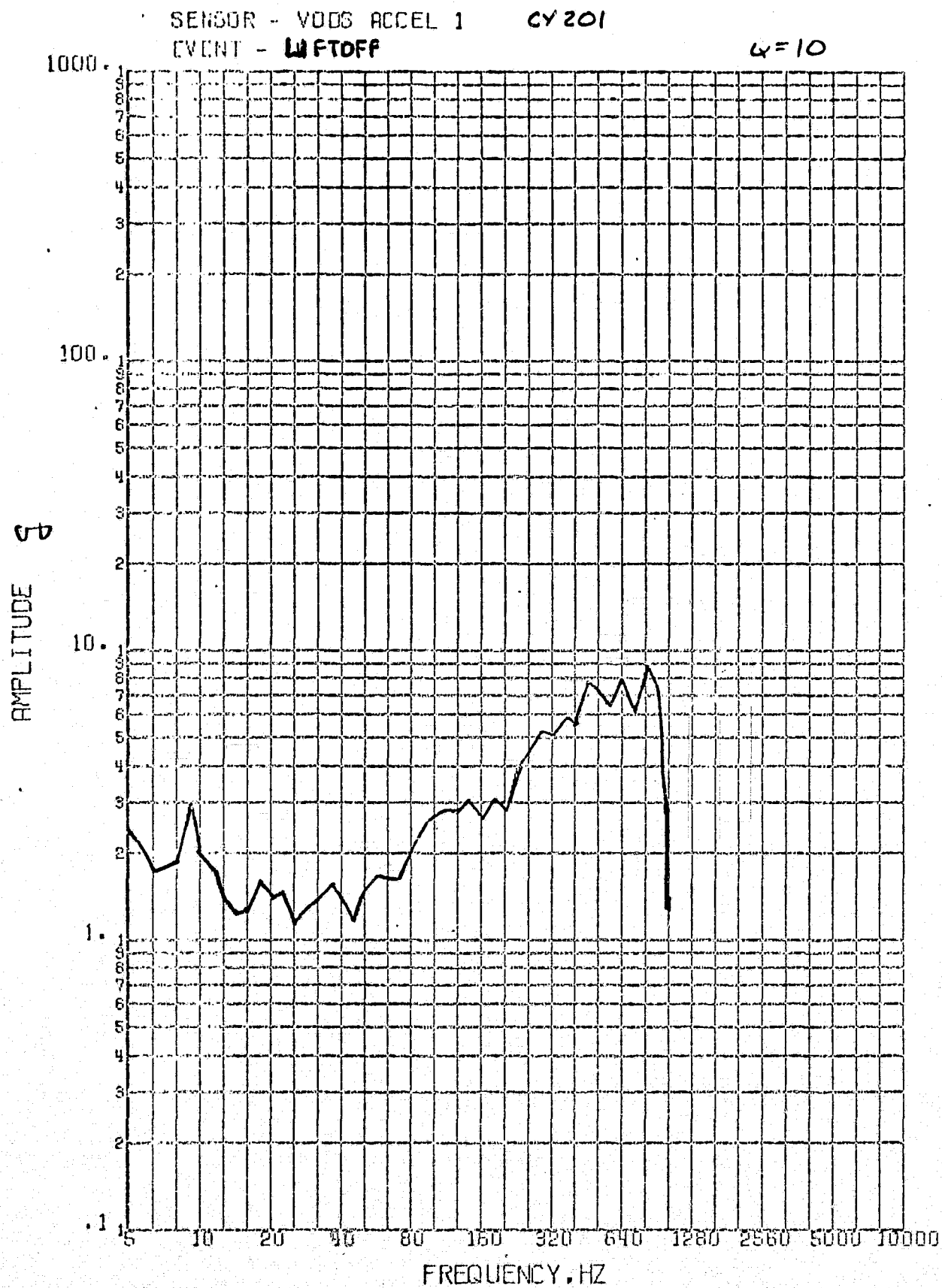


Figure 24. a

SENSOR - VDO5 ACCEL 2
EVENT - LIFTOFF

CY202

Q=10

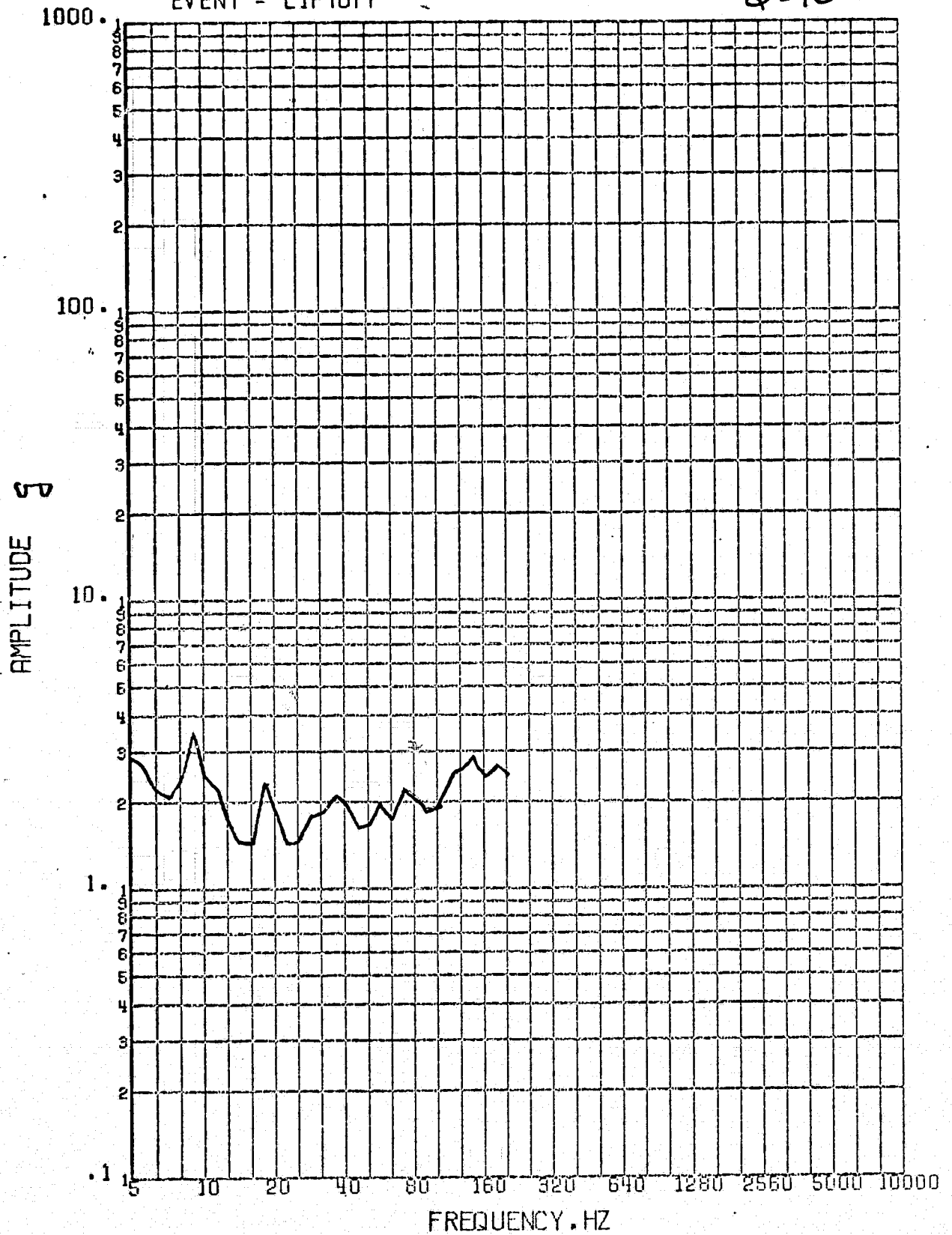


Figure 2.4 b

SENSOR - V005 ACCEL 3
EVENT - LIFTOFF

CY203

Q=10

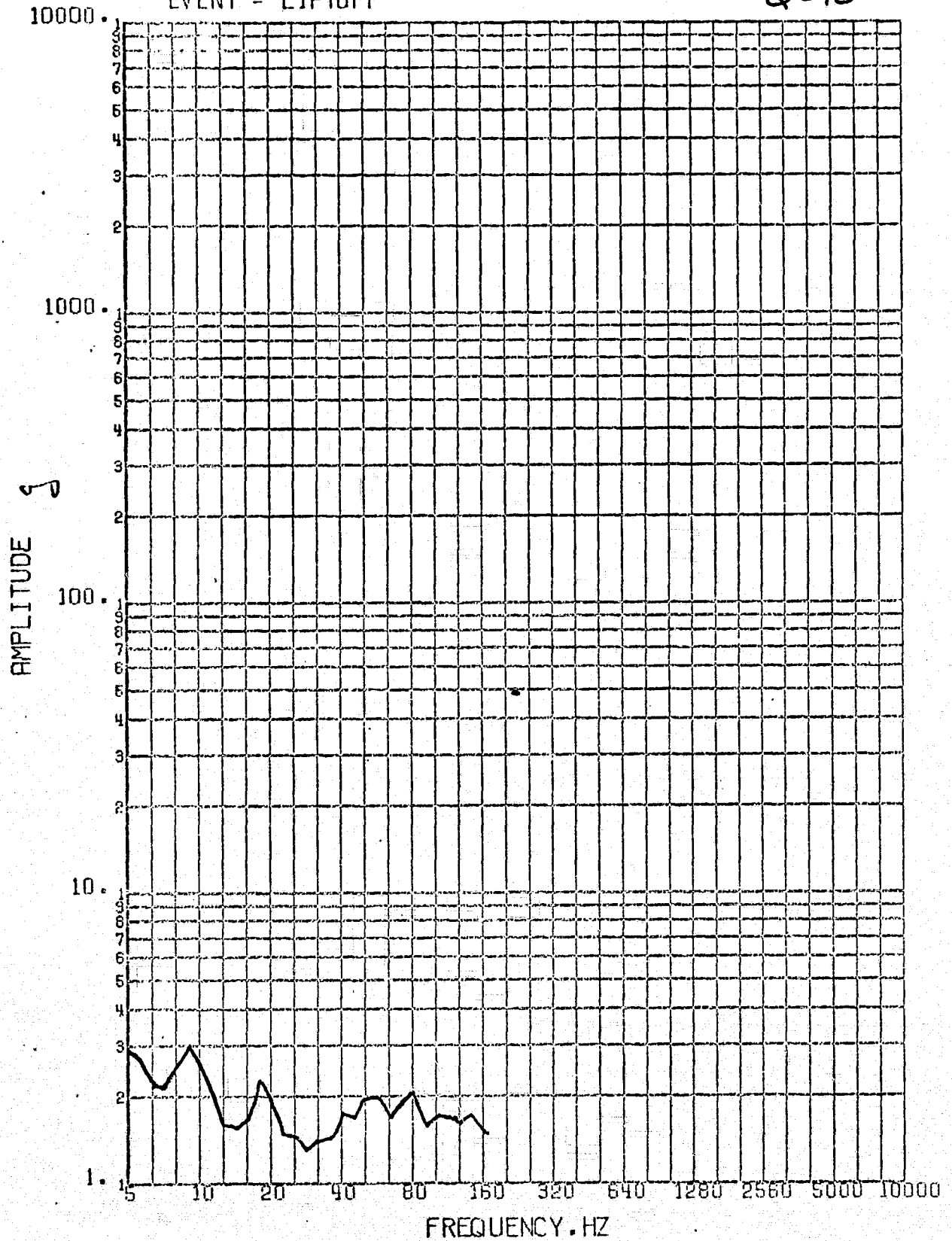


Figure 24 c

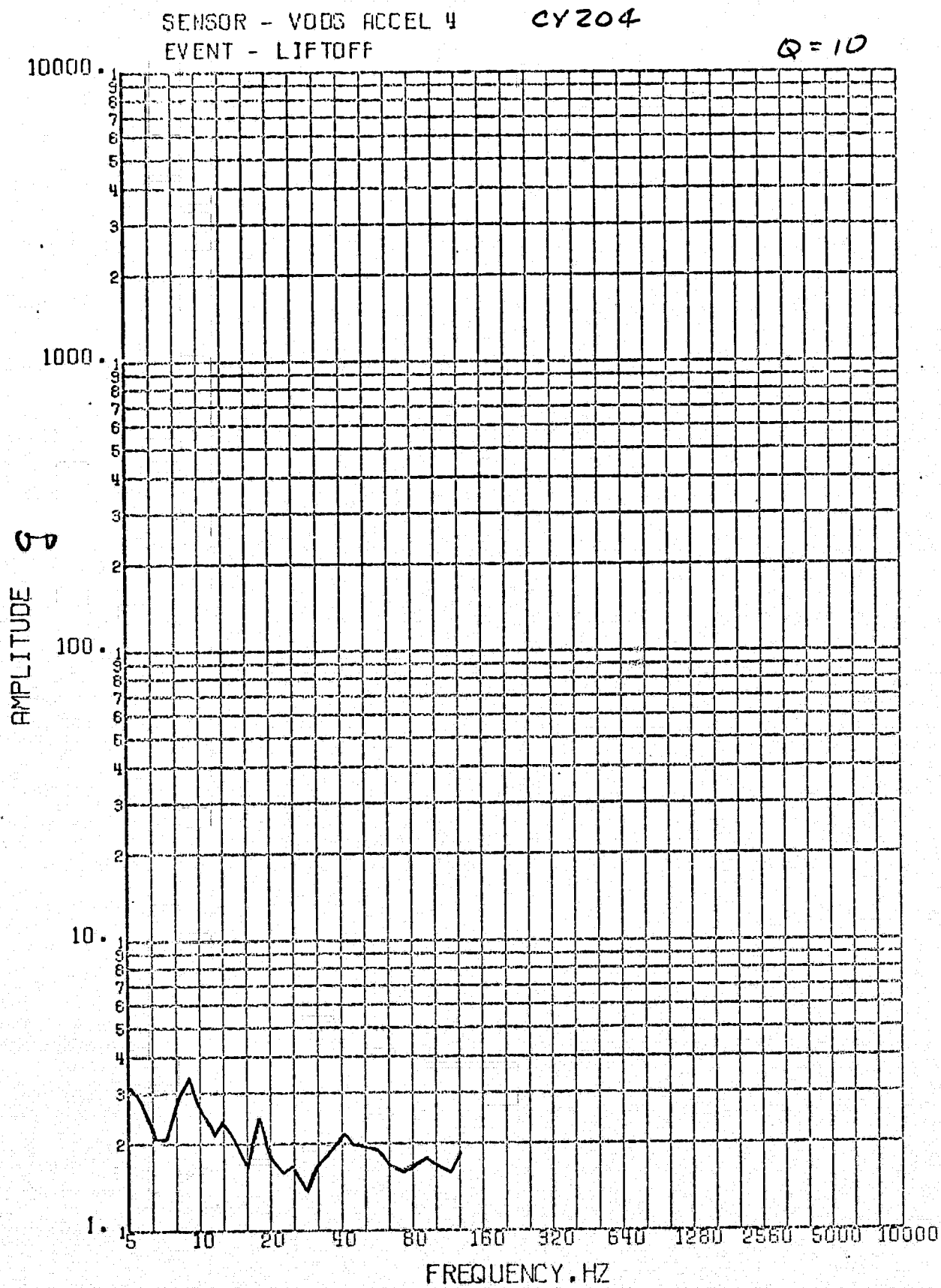


Figure 24 d

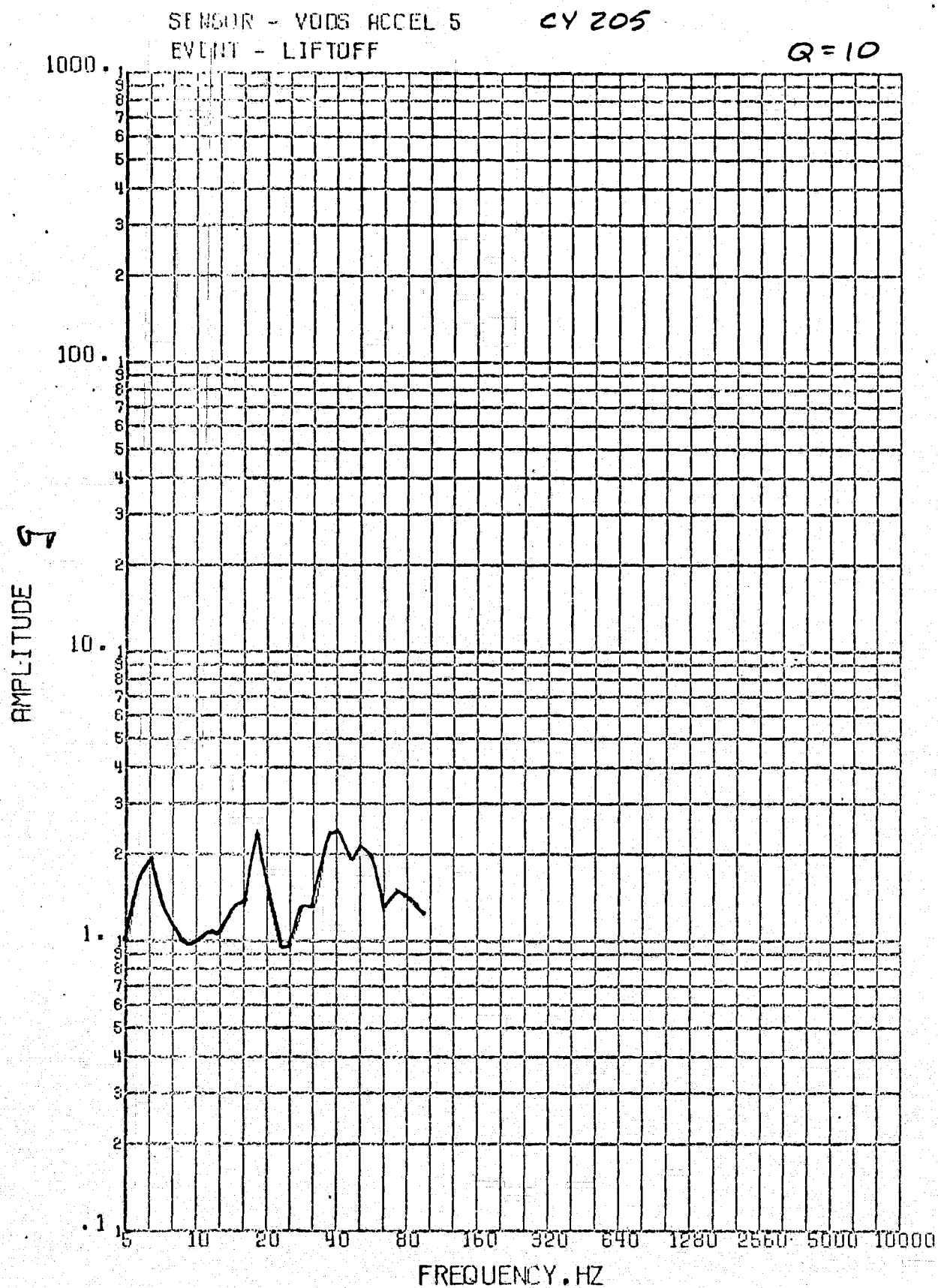


Figure 24 e

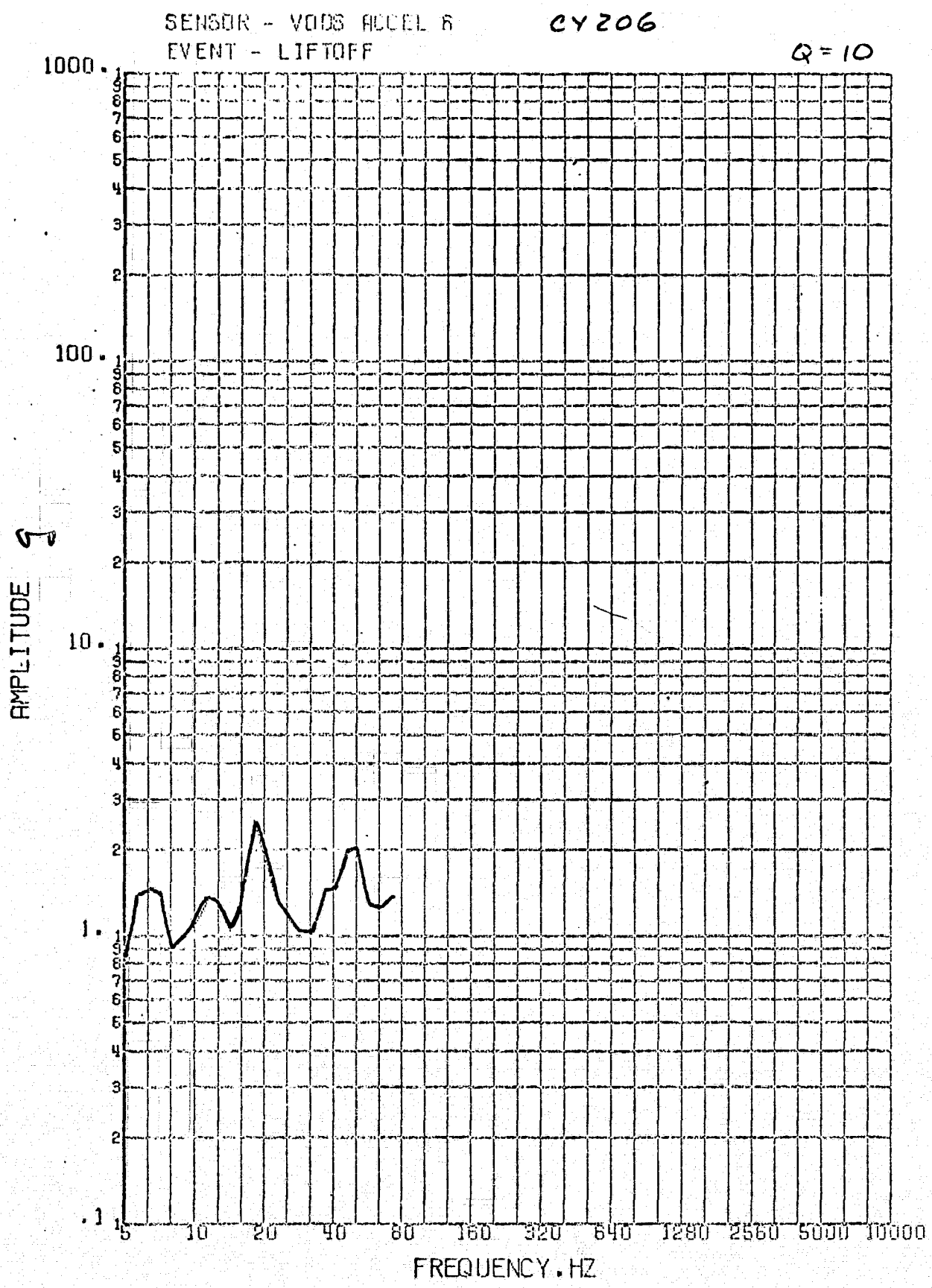
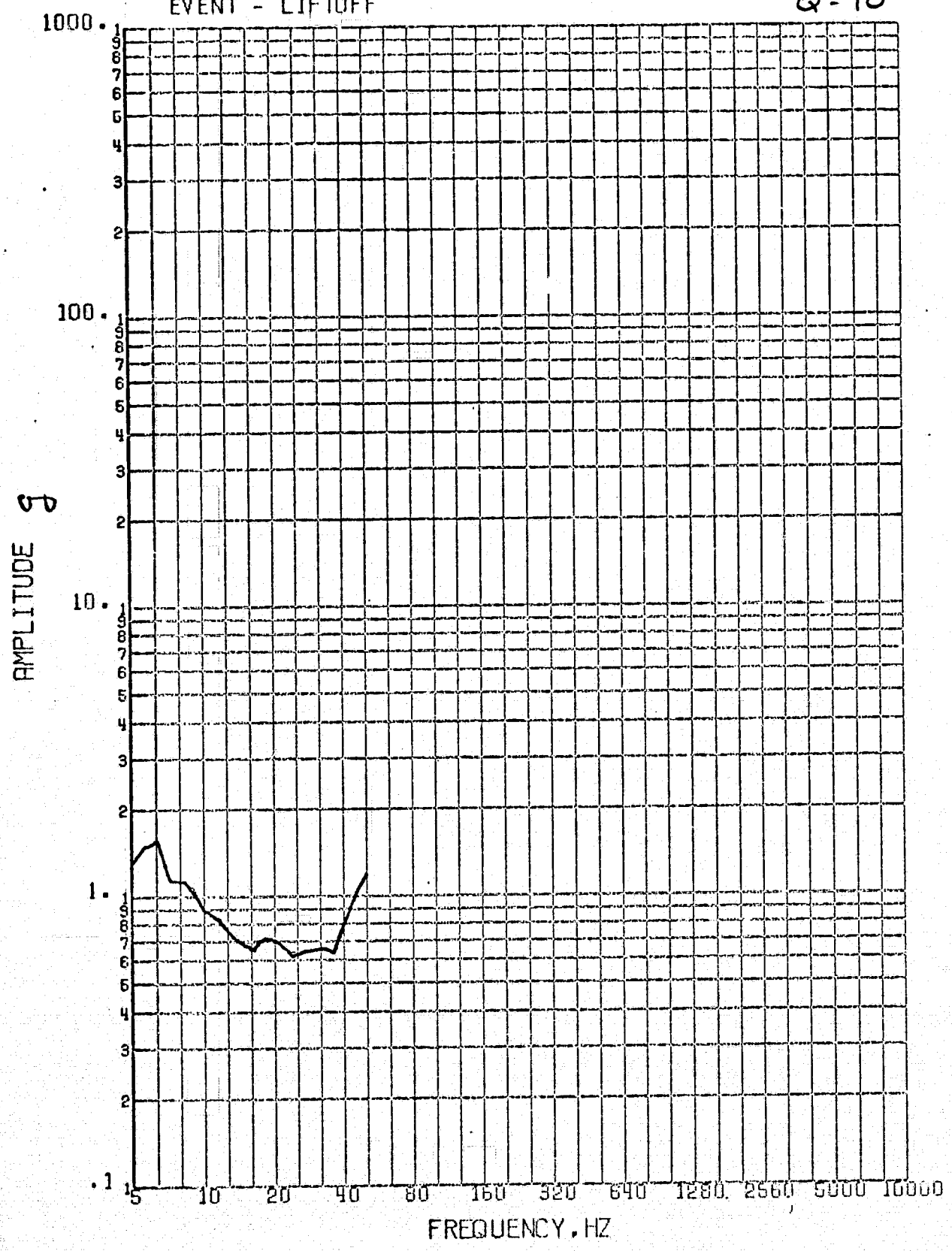


Figure 2.4 f

SENSOR - VDO5 ACCEL 7
EVENT - LIFTOFF

CY 207

Q = 10



2.15

Figure 2.4 g

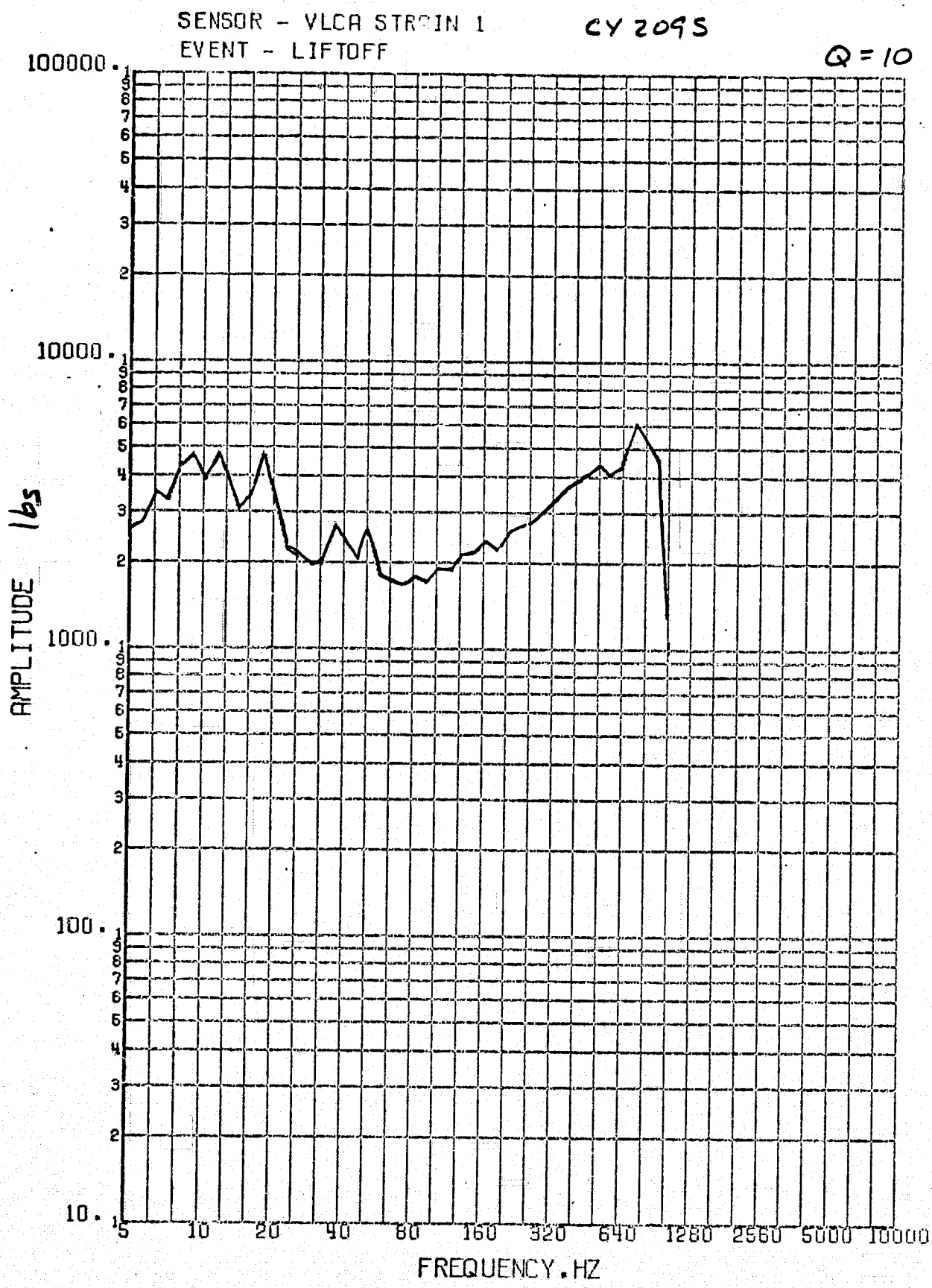


Figure 2.4 h

SENSOR - VLCA STRAIN 2
EVENT - LIFTOFF

CY2105

Q=10

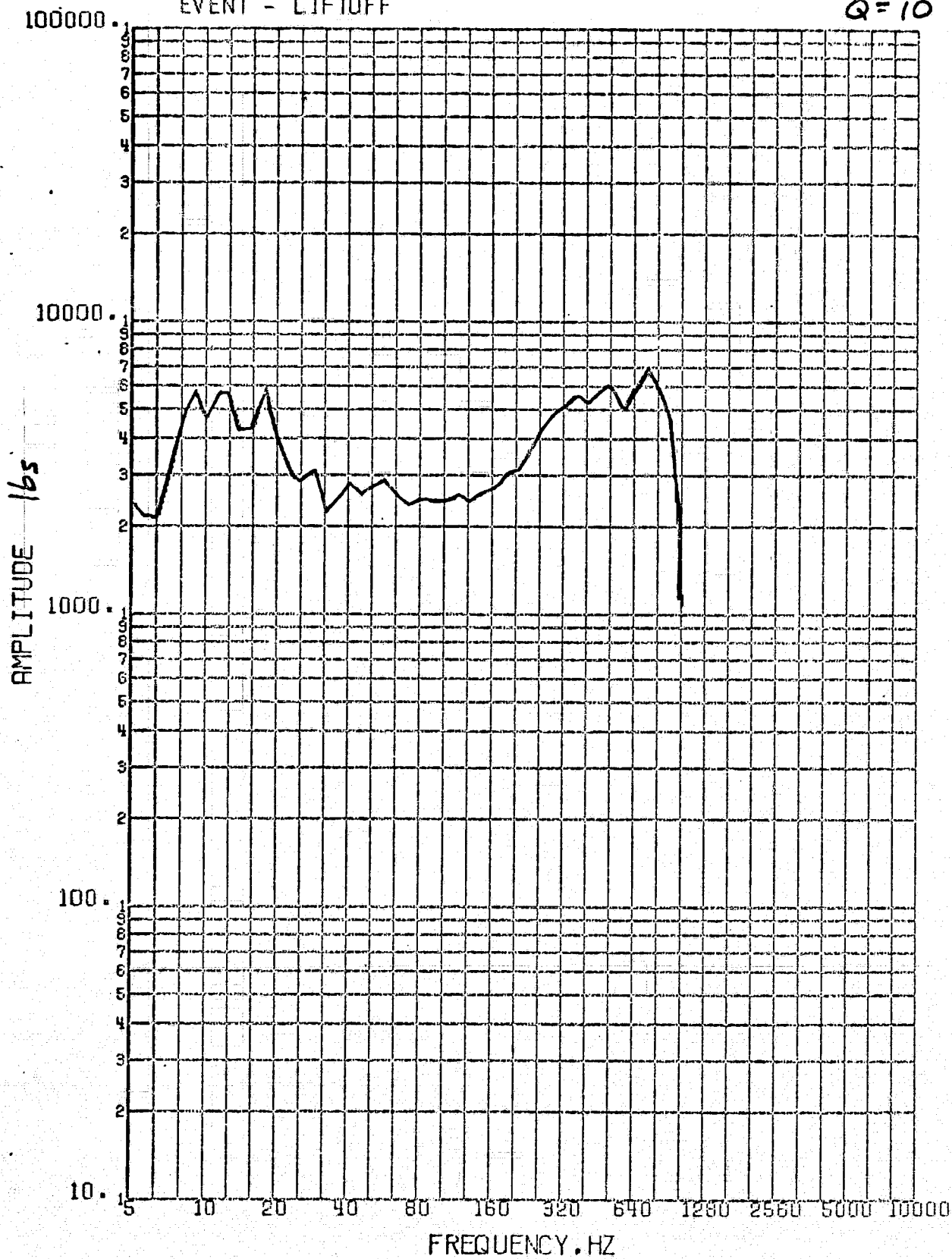


Figure 24 j

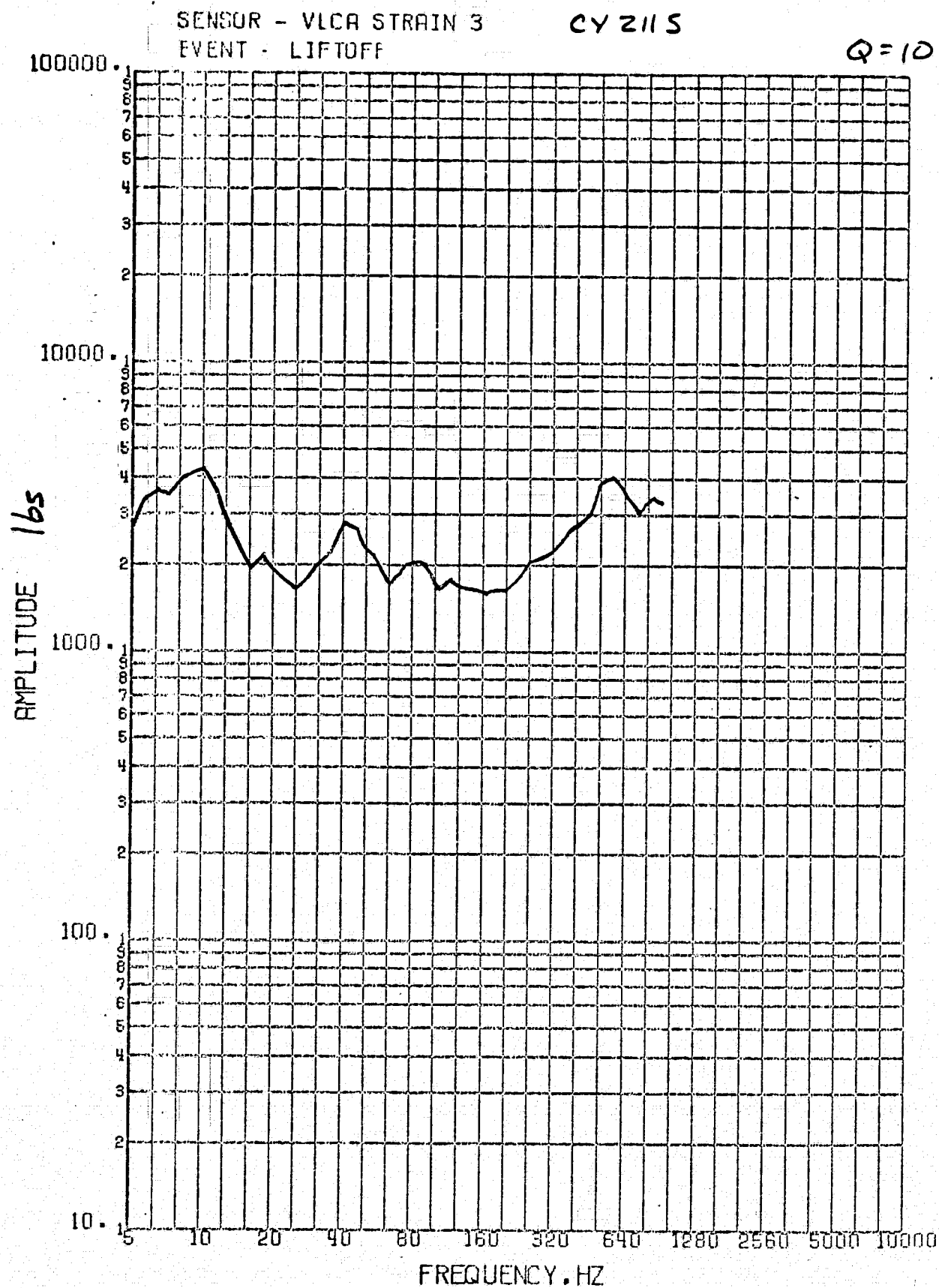


Figure 2.4 k

SENSOR - VLCA STRAIN 4
EVENT - LIFTOFF

CY 2125

Q=10

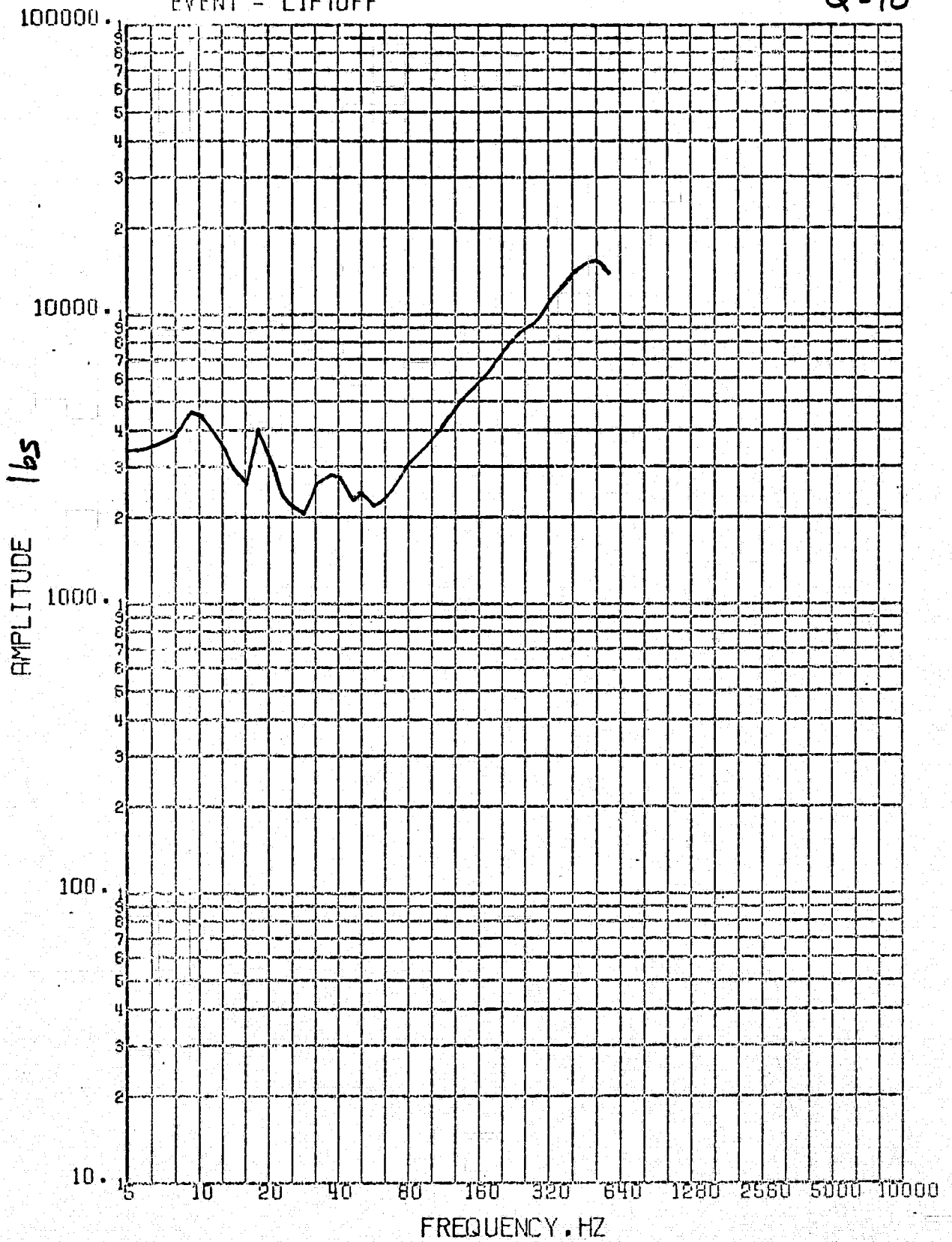
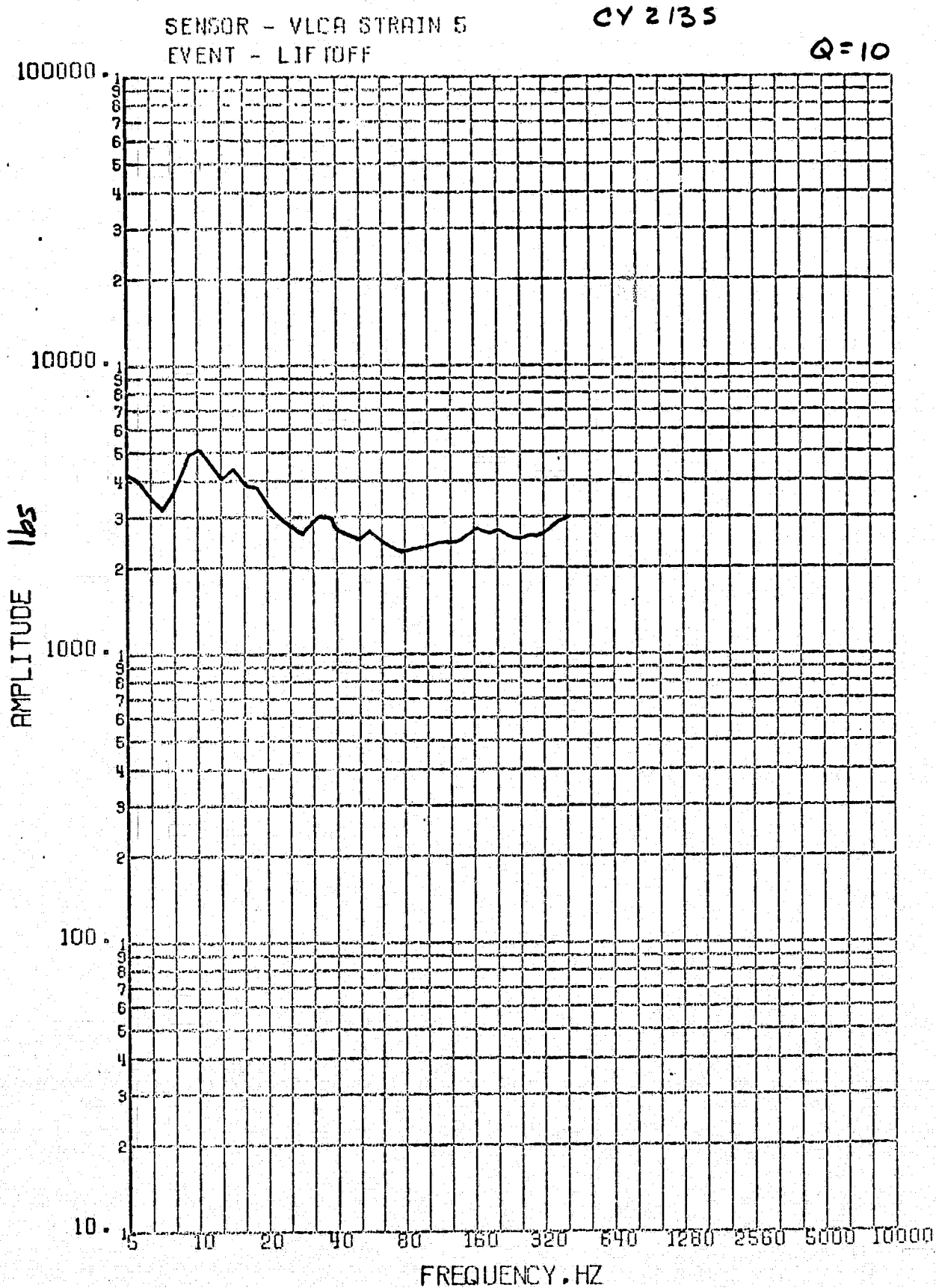


Figure 2.4 e



2.10

Figure 24 m

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SENSOR - VDD5 ACCEL 1. CY201. Z
EVENT - FBR RELEASE

Q=10

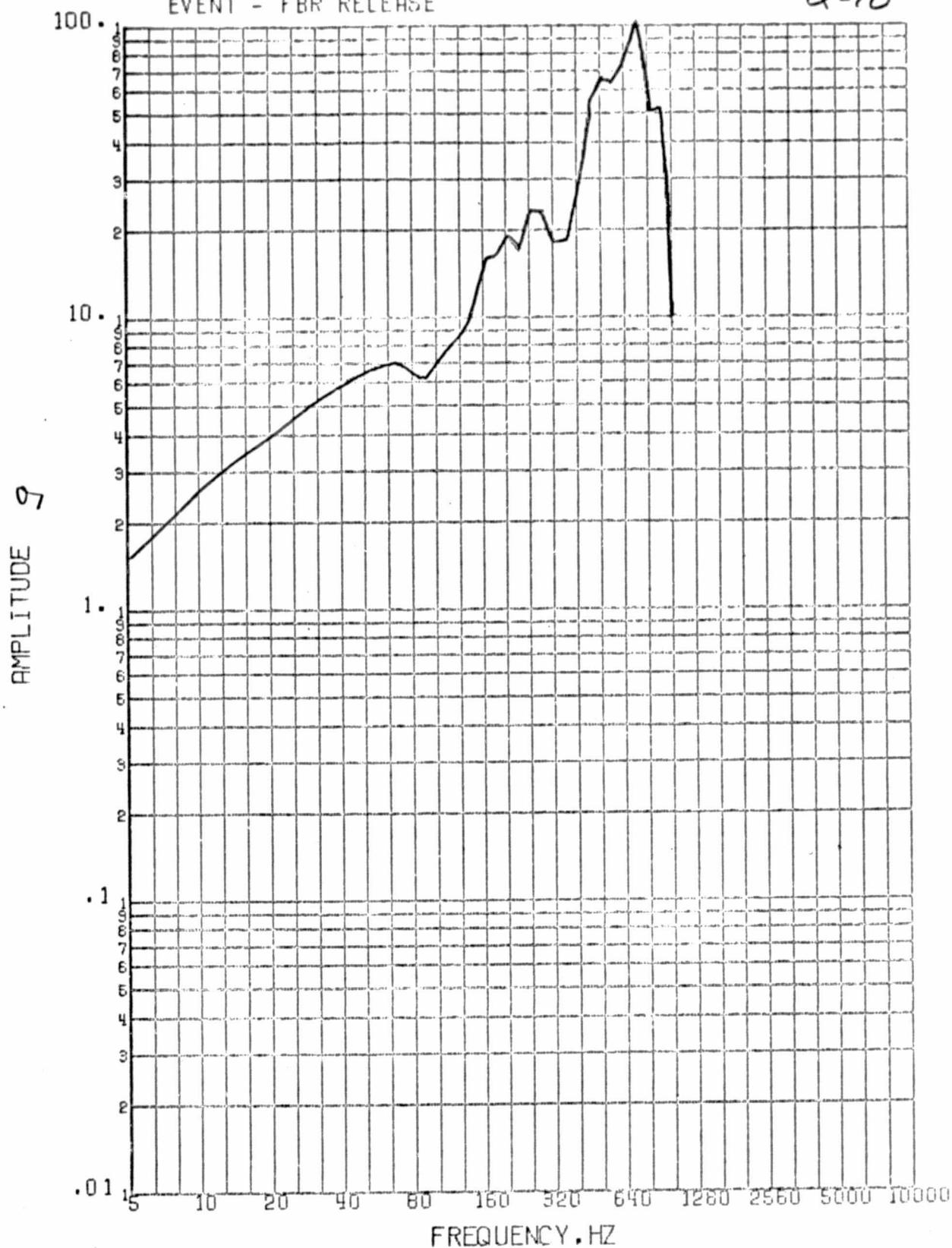


Figure 2.5 a

4-9-74

SENSOR - VODS ACCEL. 1, CY201, Z
EVENT - FBR RELEASE

Q=10

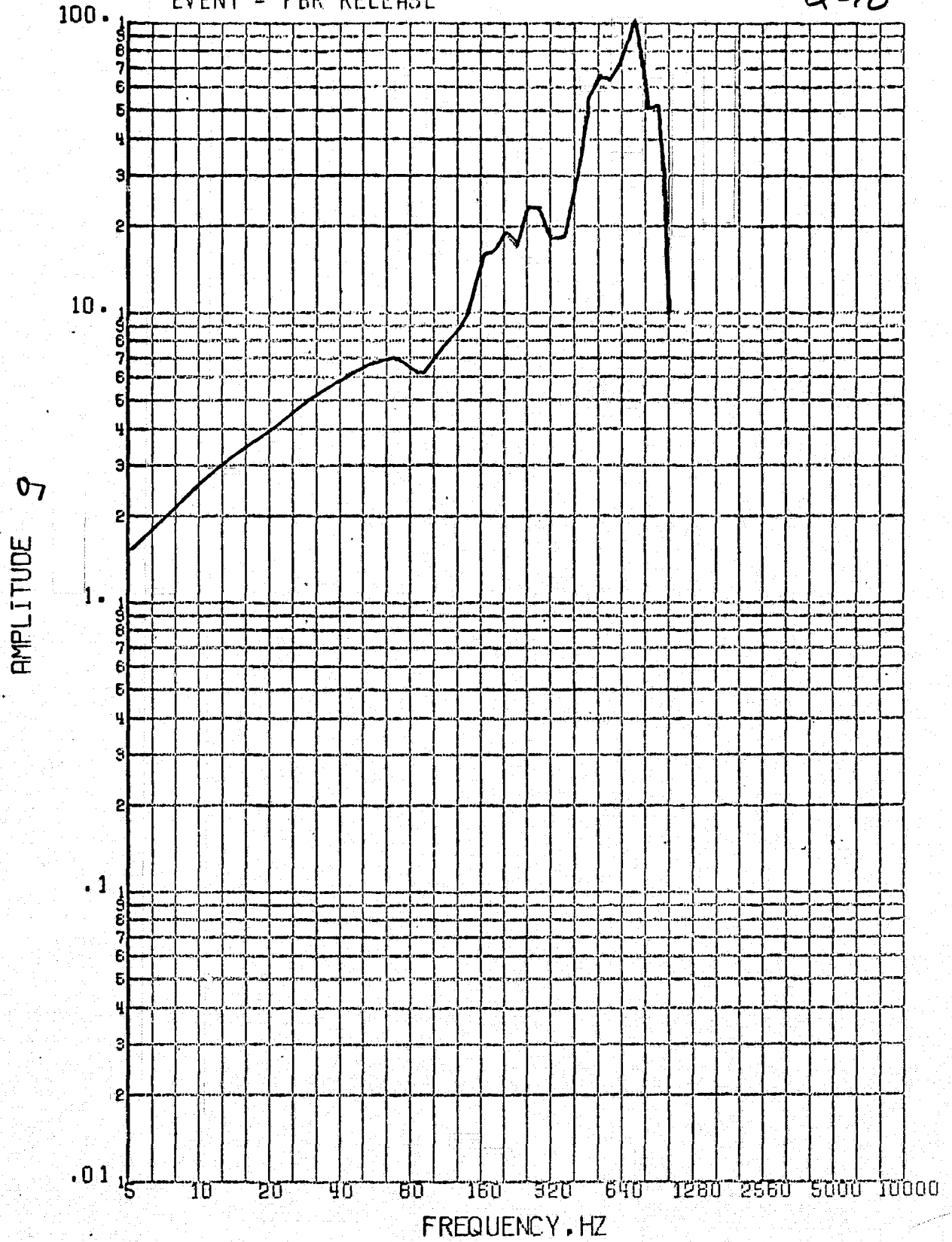


Figure 2.5 a

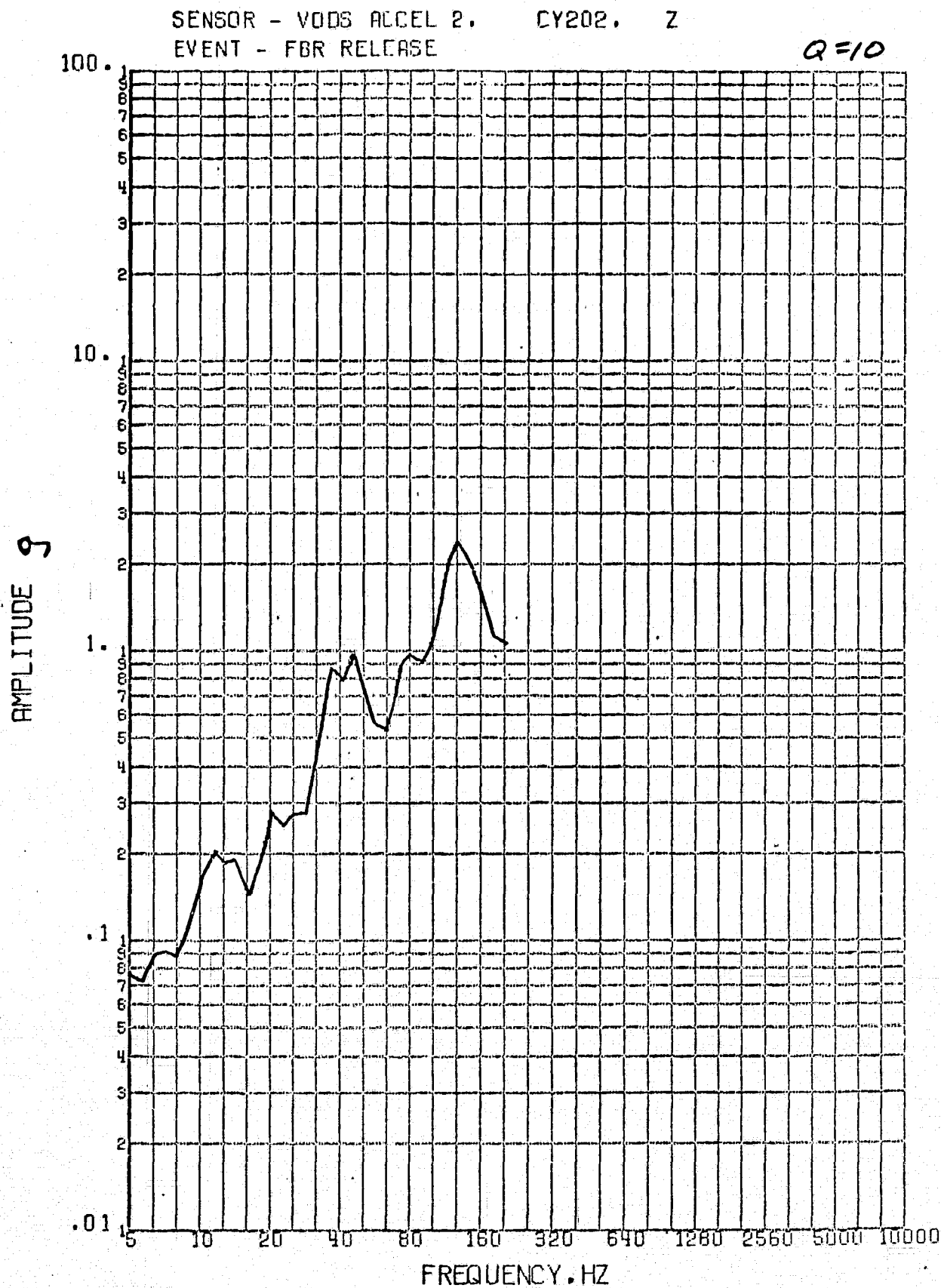


Figure 2.5 b

4-9-74

SENSOR - VDOIS ACCEL 3, CY203, Z
EVENT - FBR RELEASE

Q=10

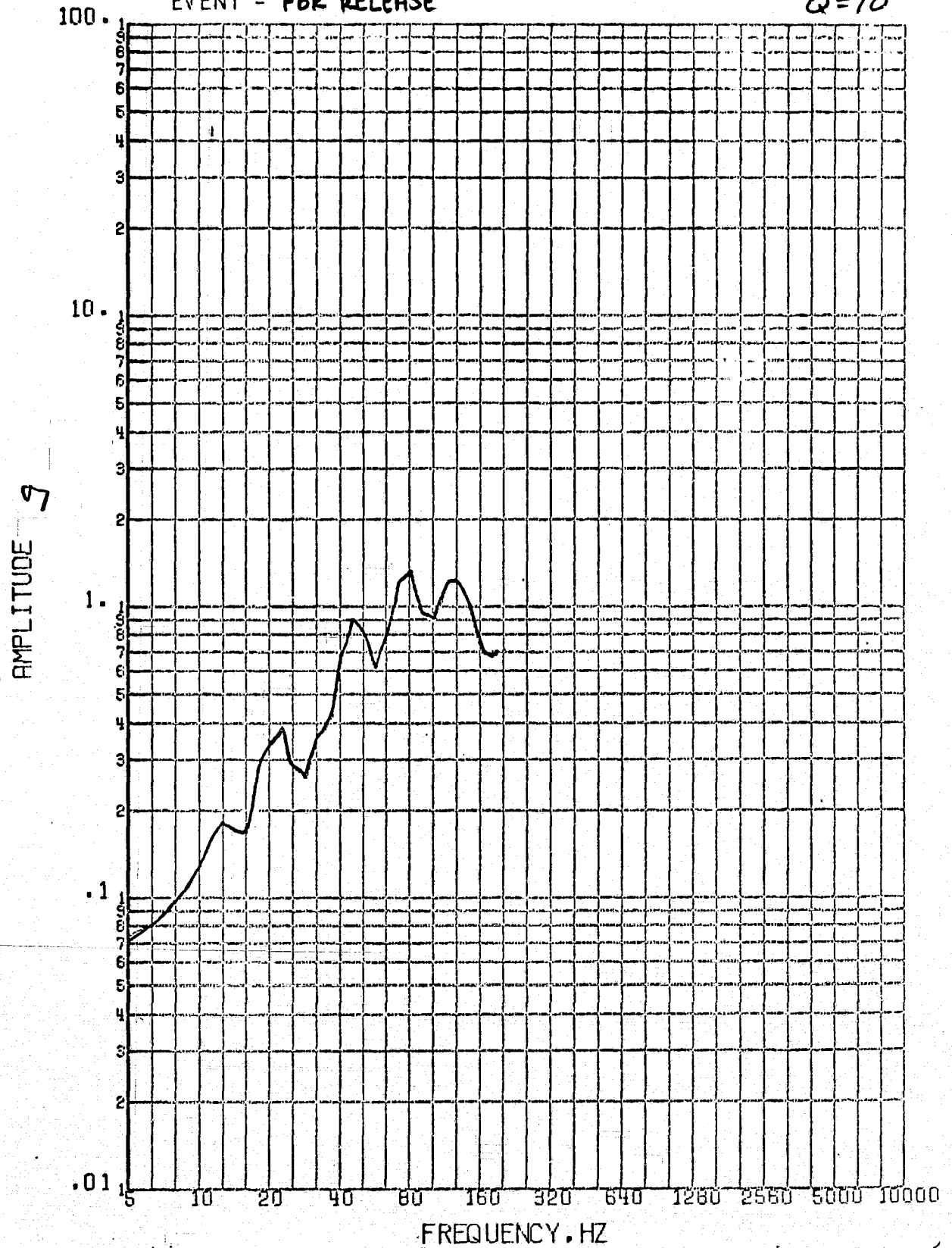


Figure 2.5 c

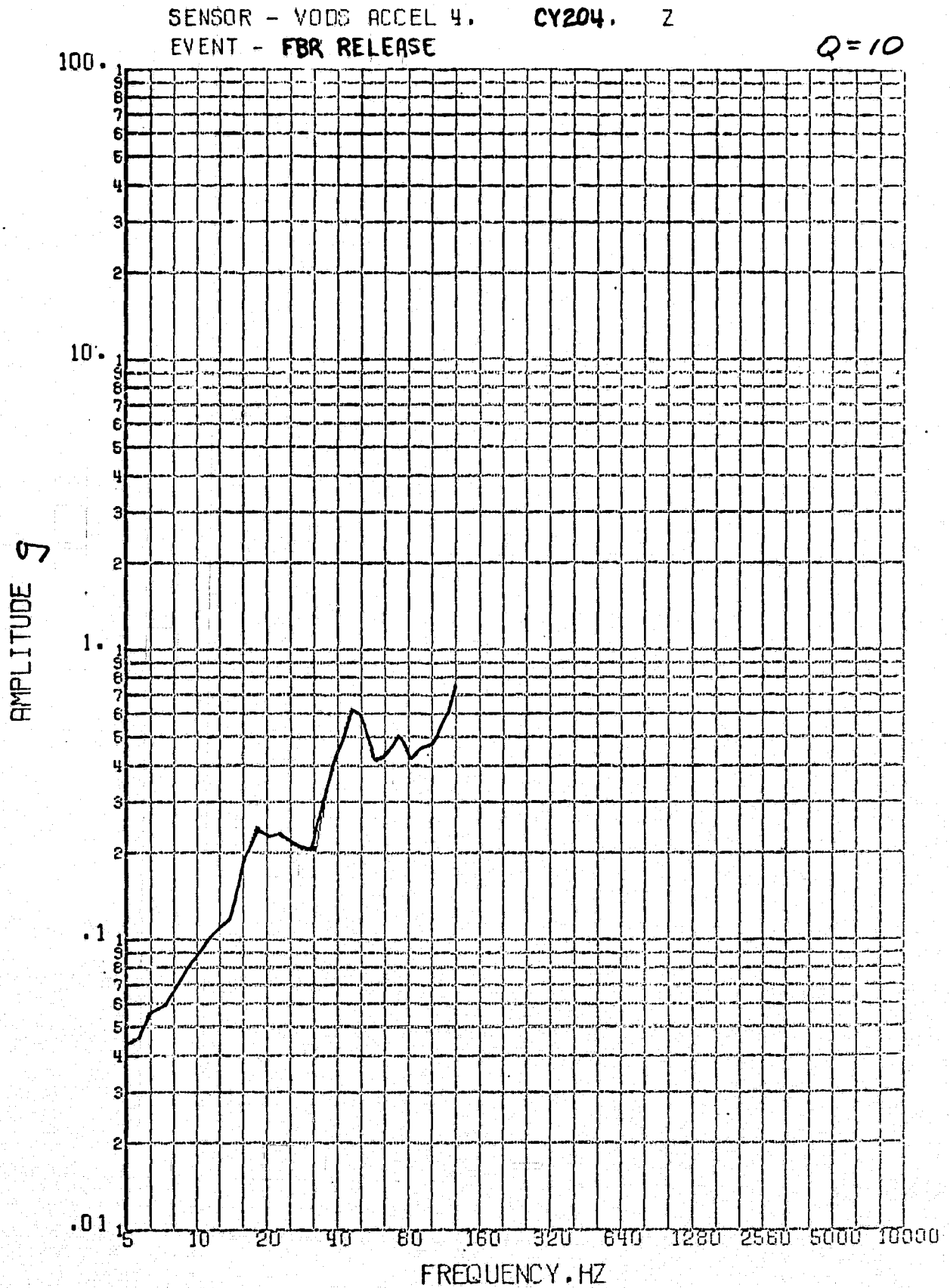
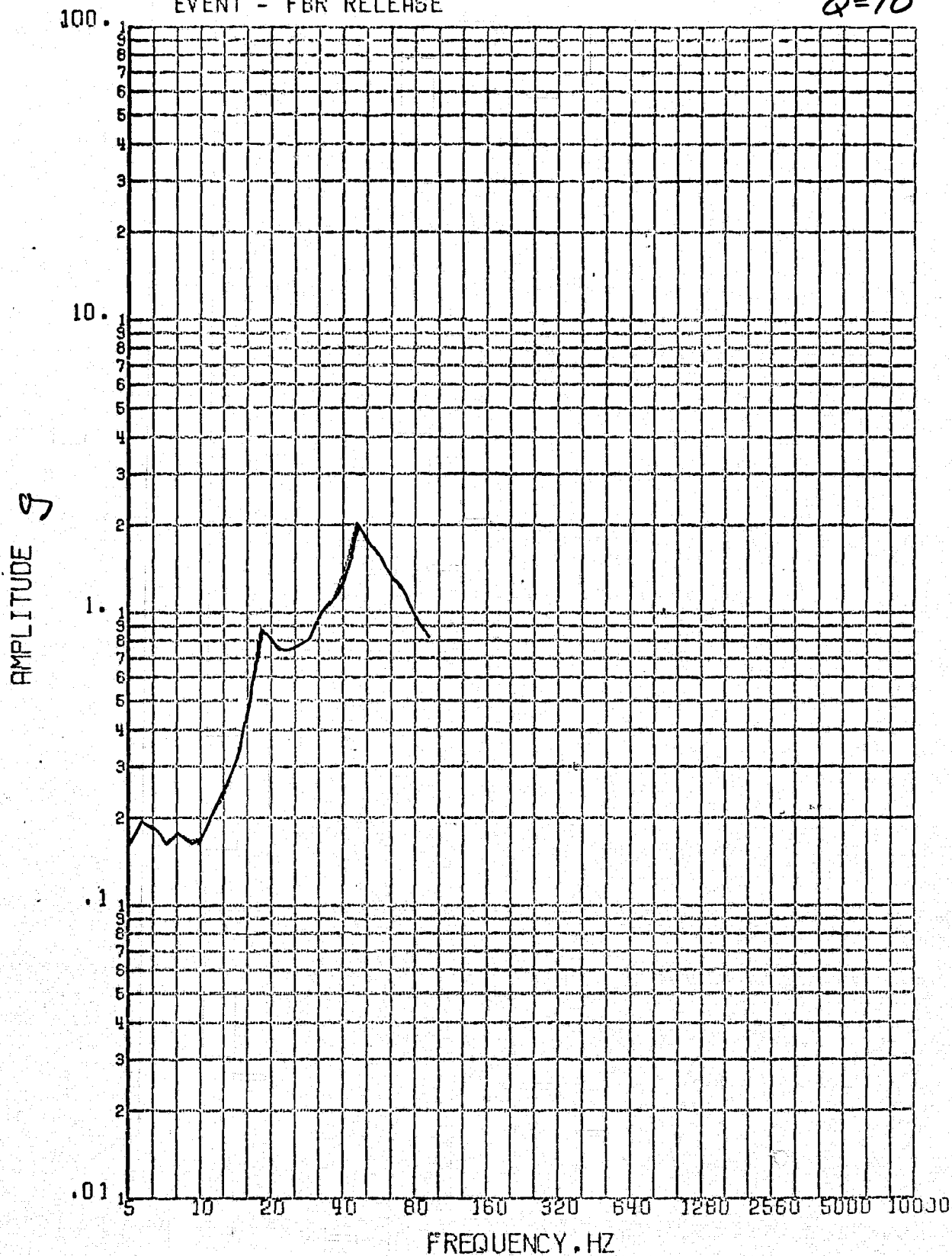


Figure 2.5 d

SENSOR - VQDS ACCEL 5, CY205, Y
EVENT - FBR RELEASE

Q=10

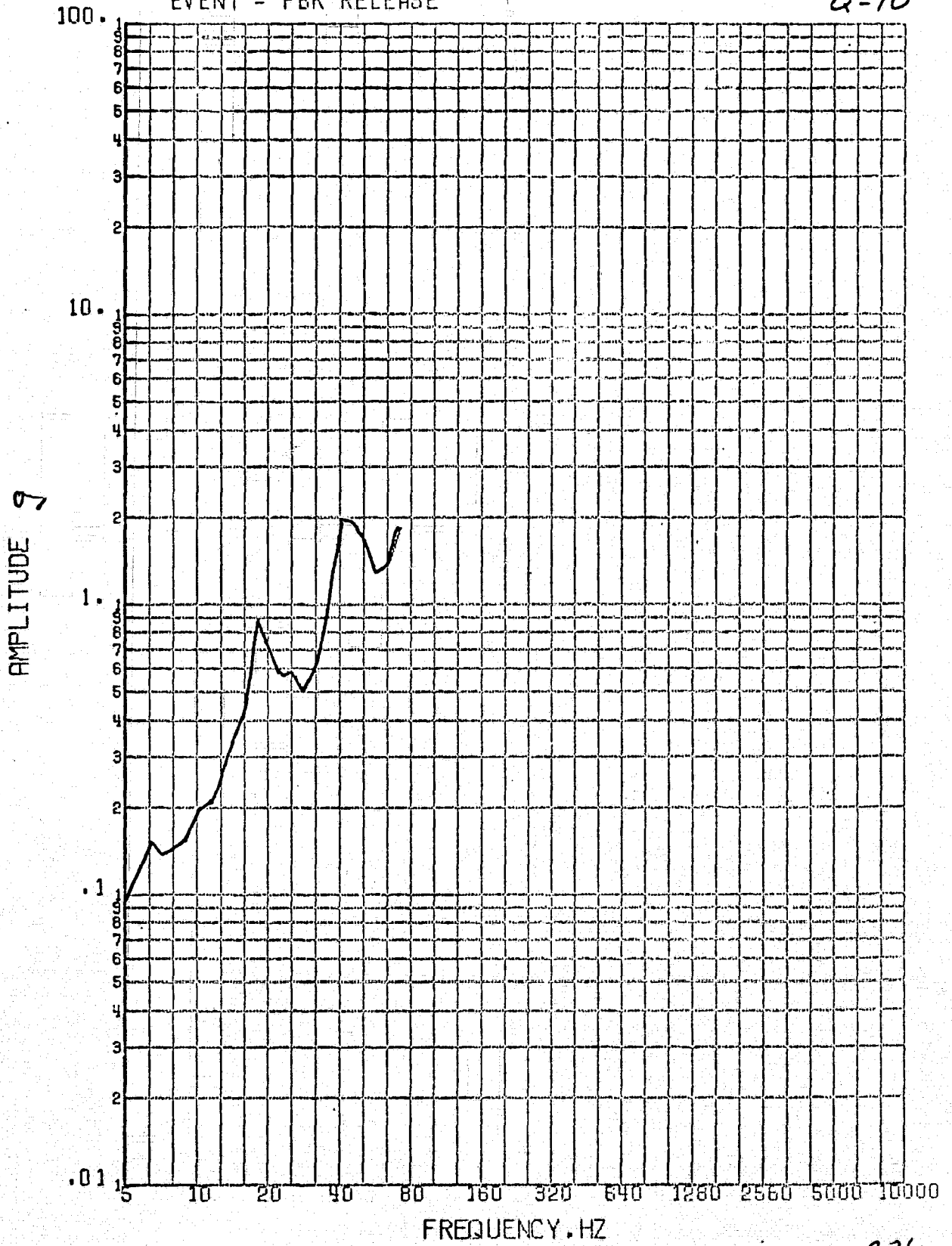


2.25

Figure 5 e

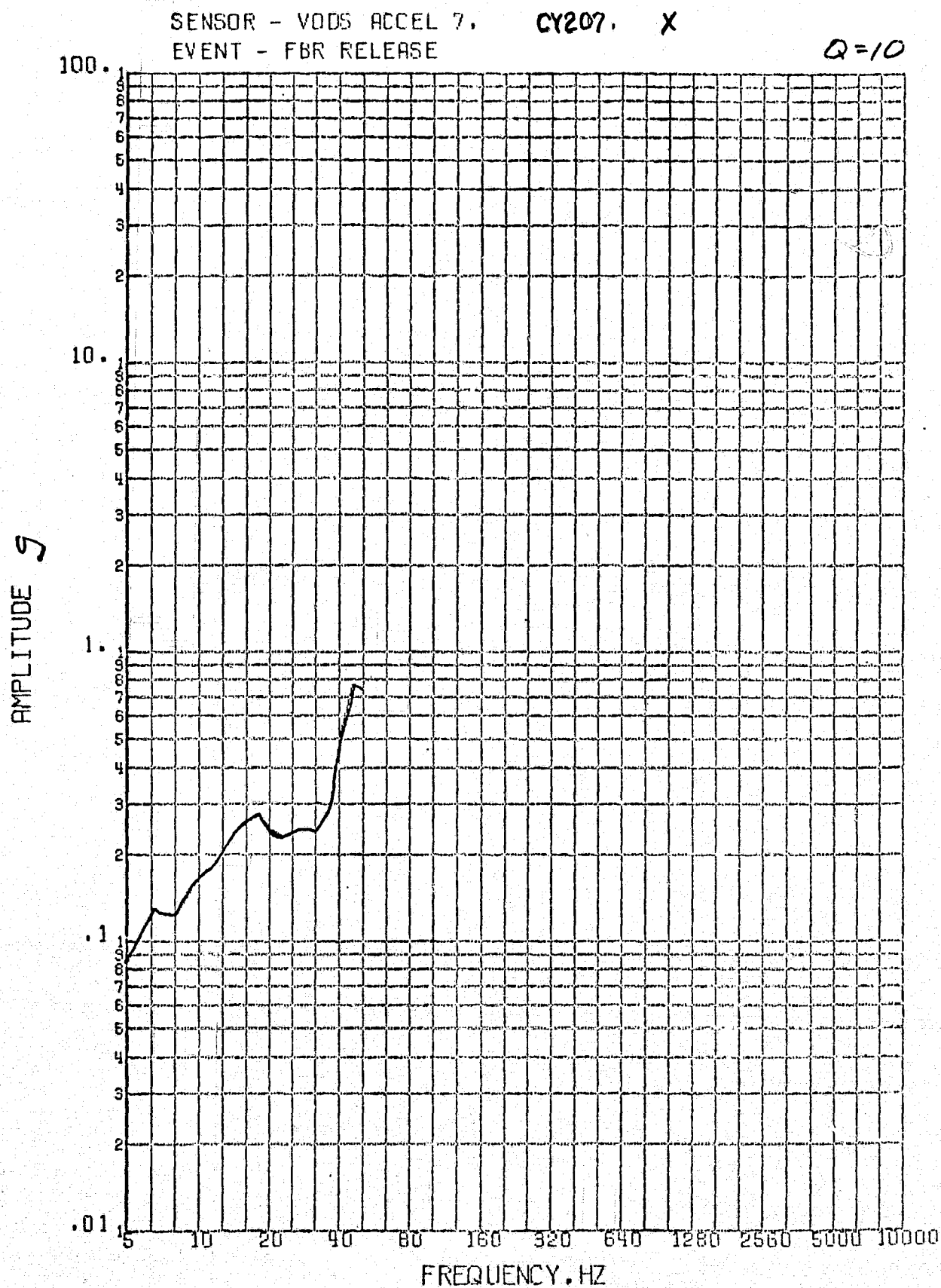
SENSOR - VDO5 ACCEL 6, CY206. Y
EVENT - FBR RELEASE

Q=10



2.26

Figure 5 f



2.27

Figure 5 g

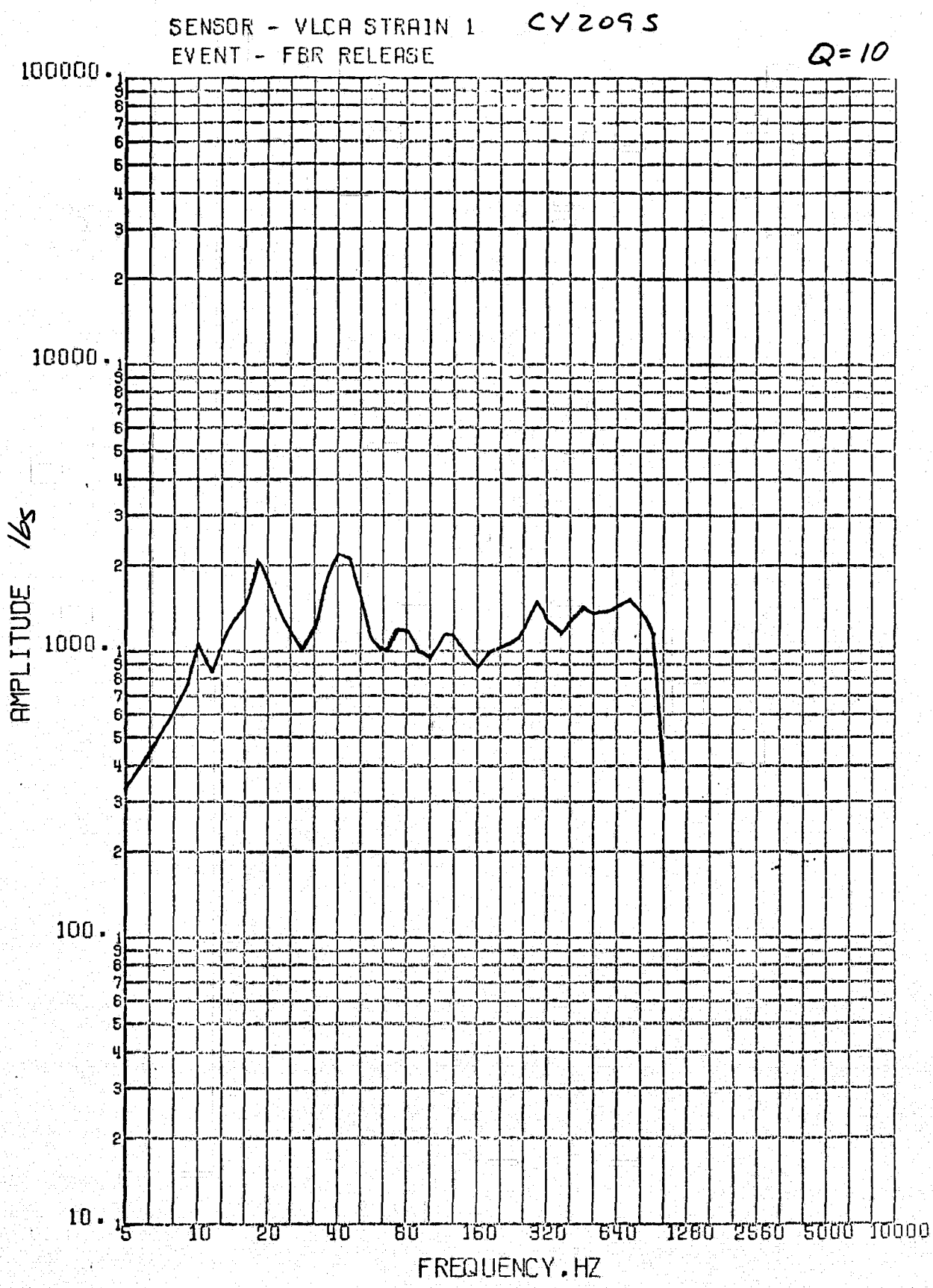


Figure 5h

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4-9-74

SENSOR - VLCA STRAIN 2 CY 2105
EVENT - FBR RELEASE

Q = 10

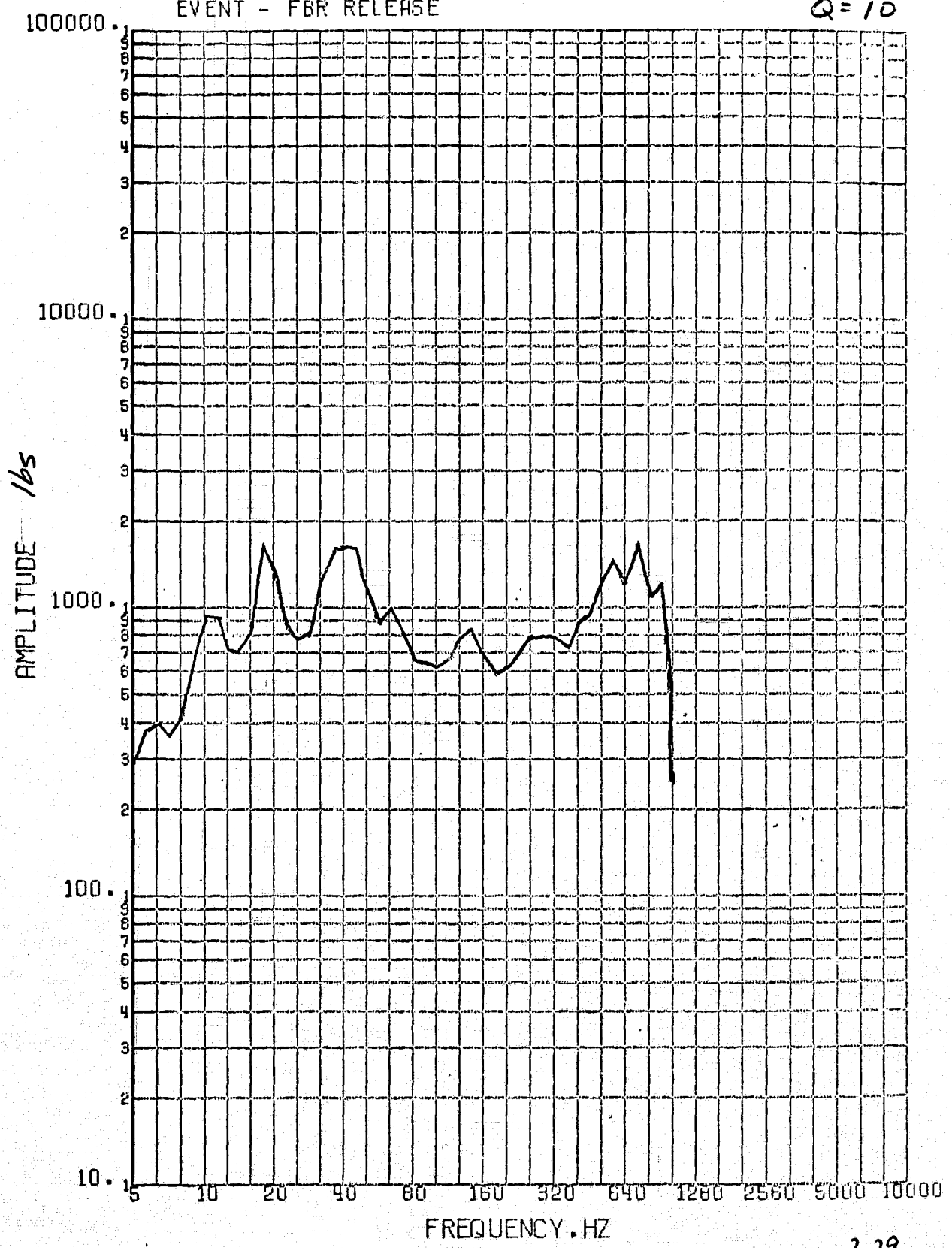


Figure 5 f

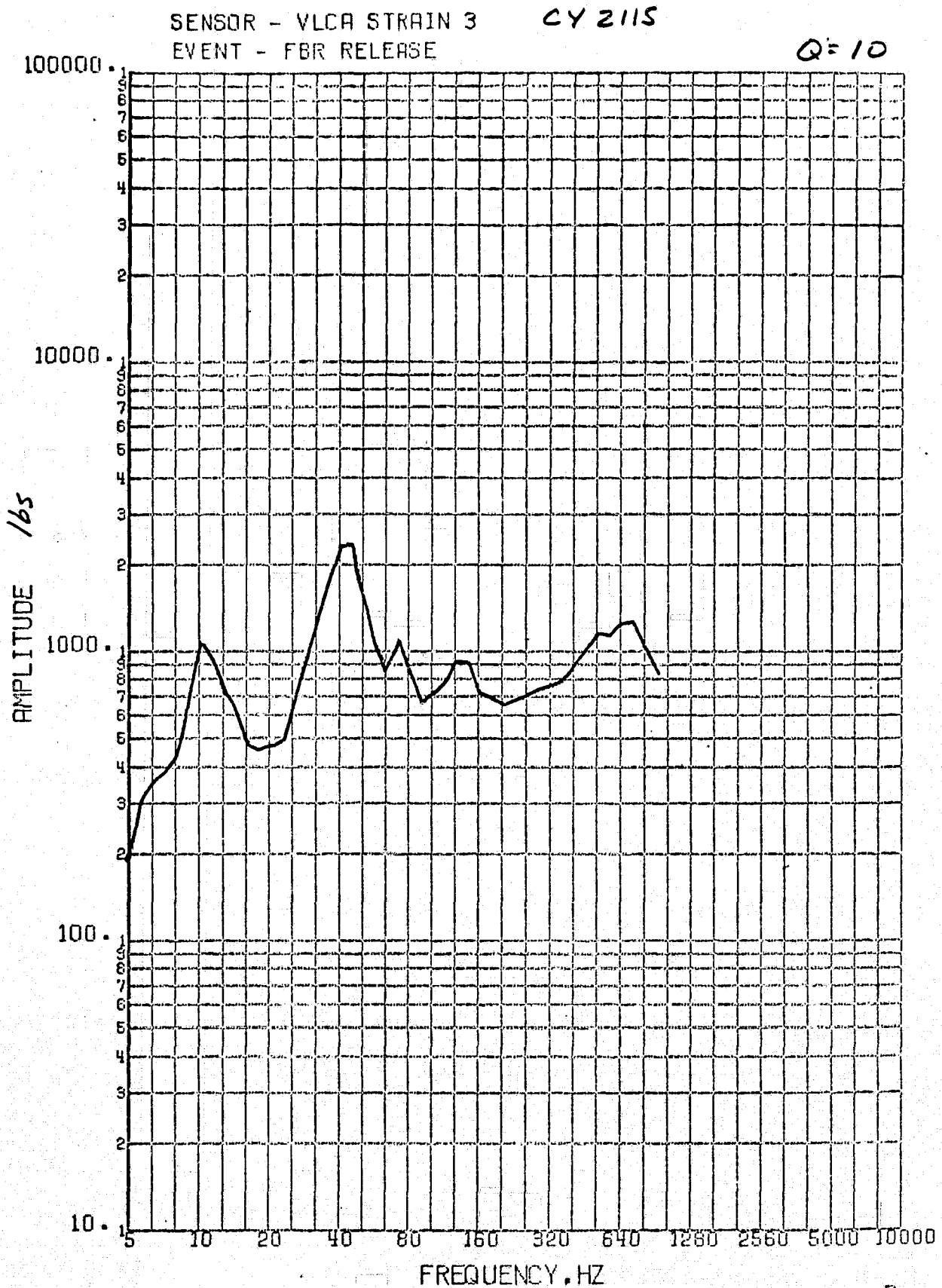


Figure 5 k

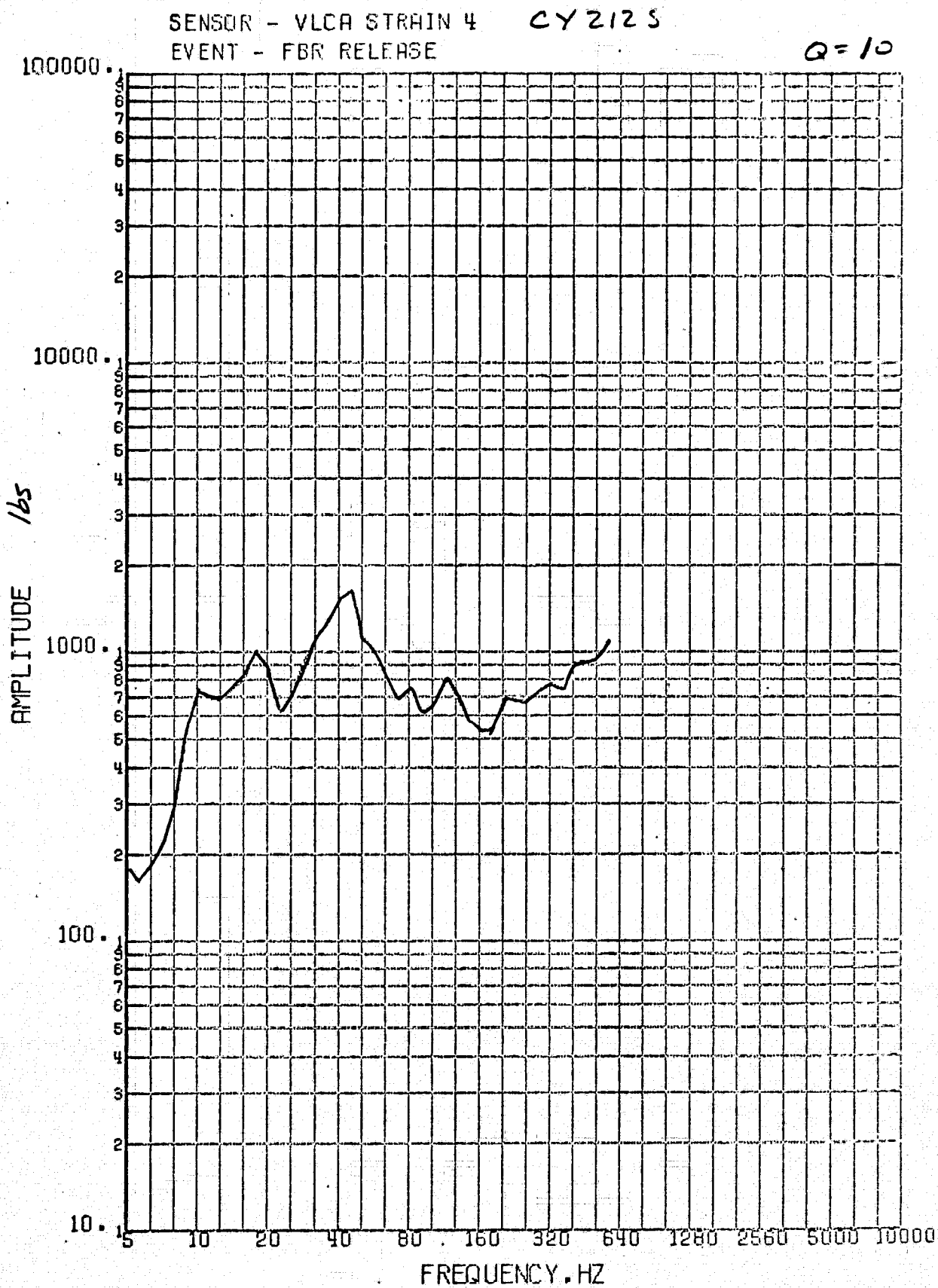
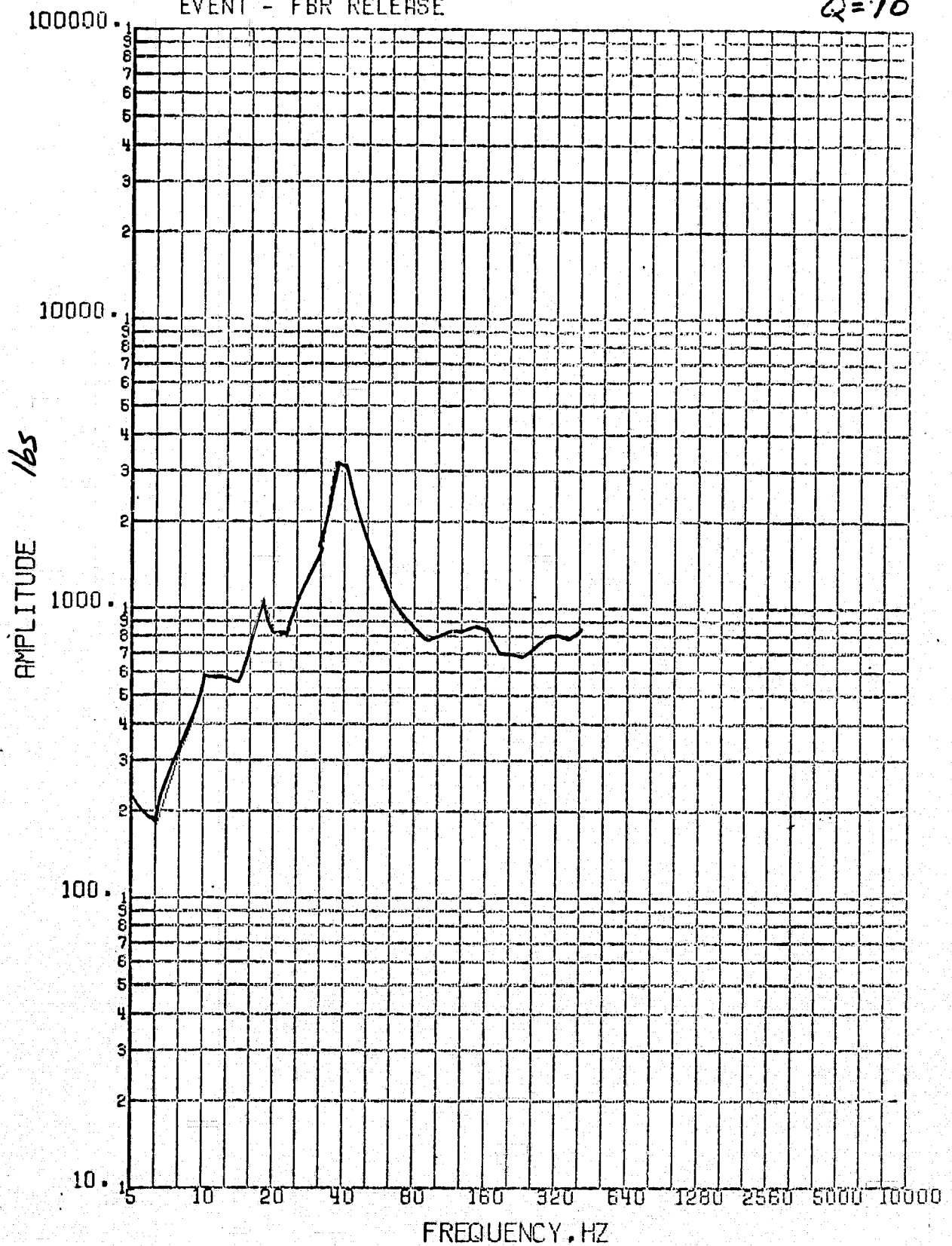


Figure 5 l

SENSOR - VLCA STRAIN 5
EVENT - FBR RELEASE

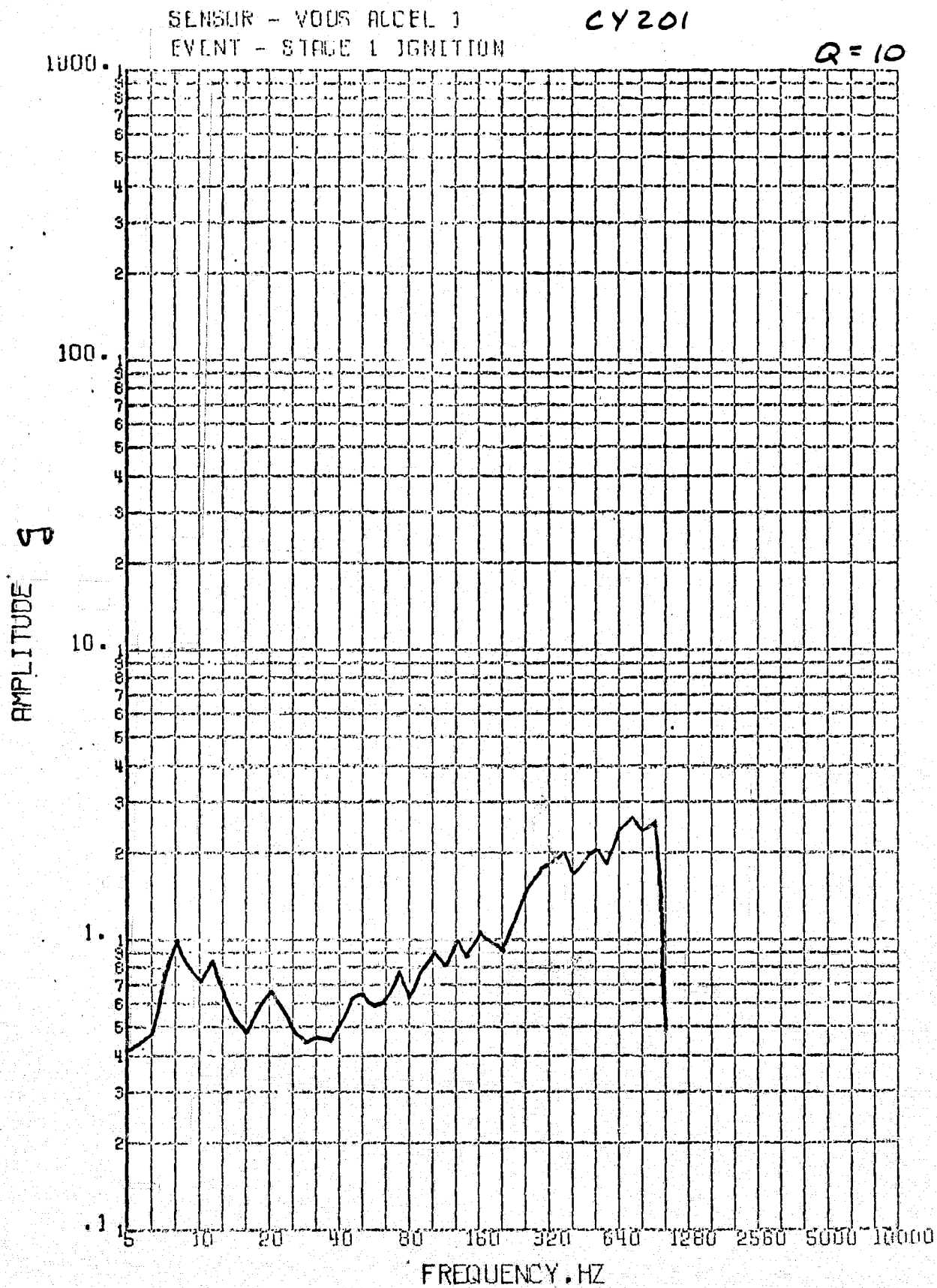
CY 213 S

Q=10



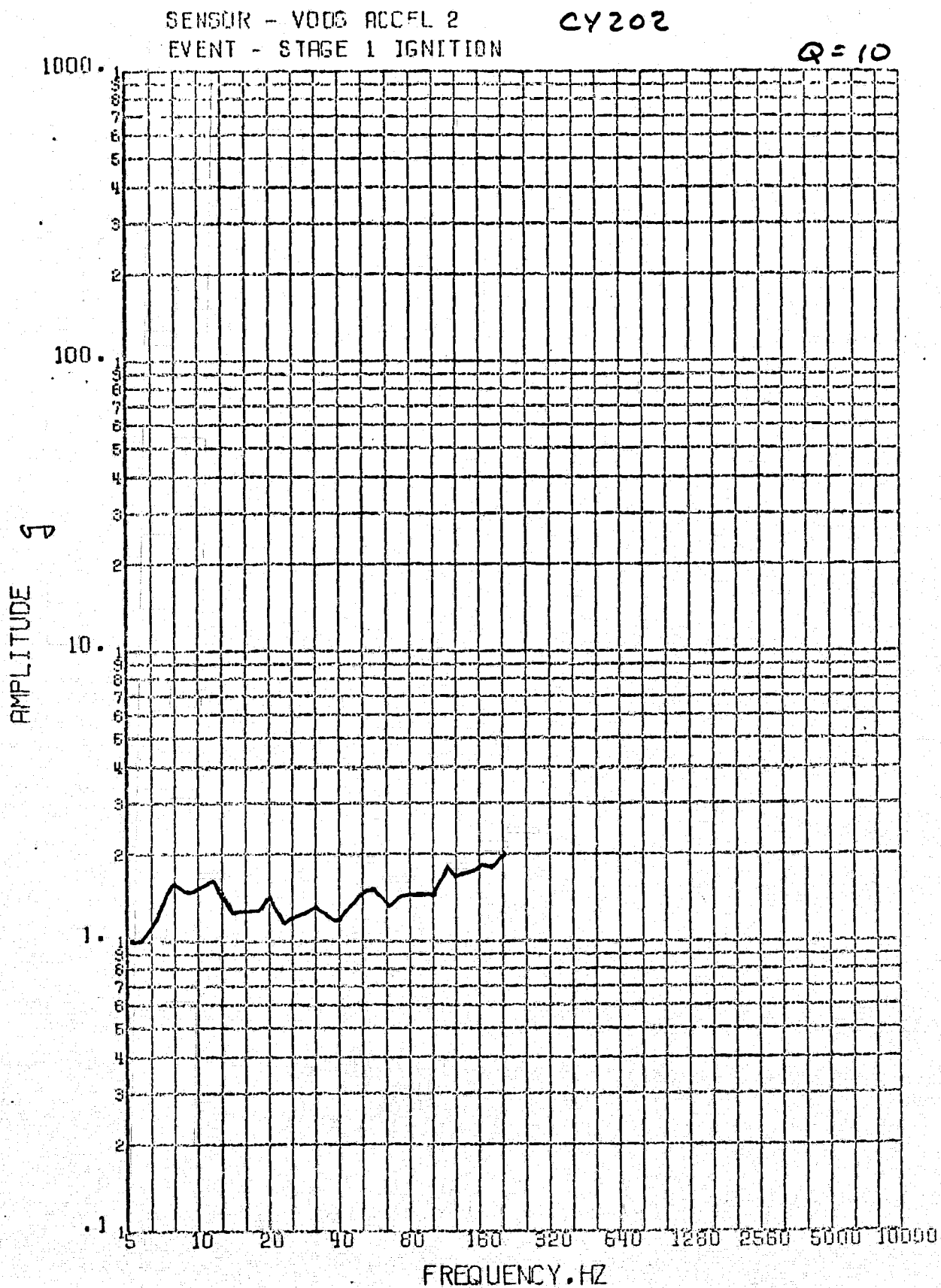
2.32

Figure 5 m



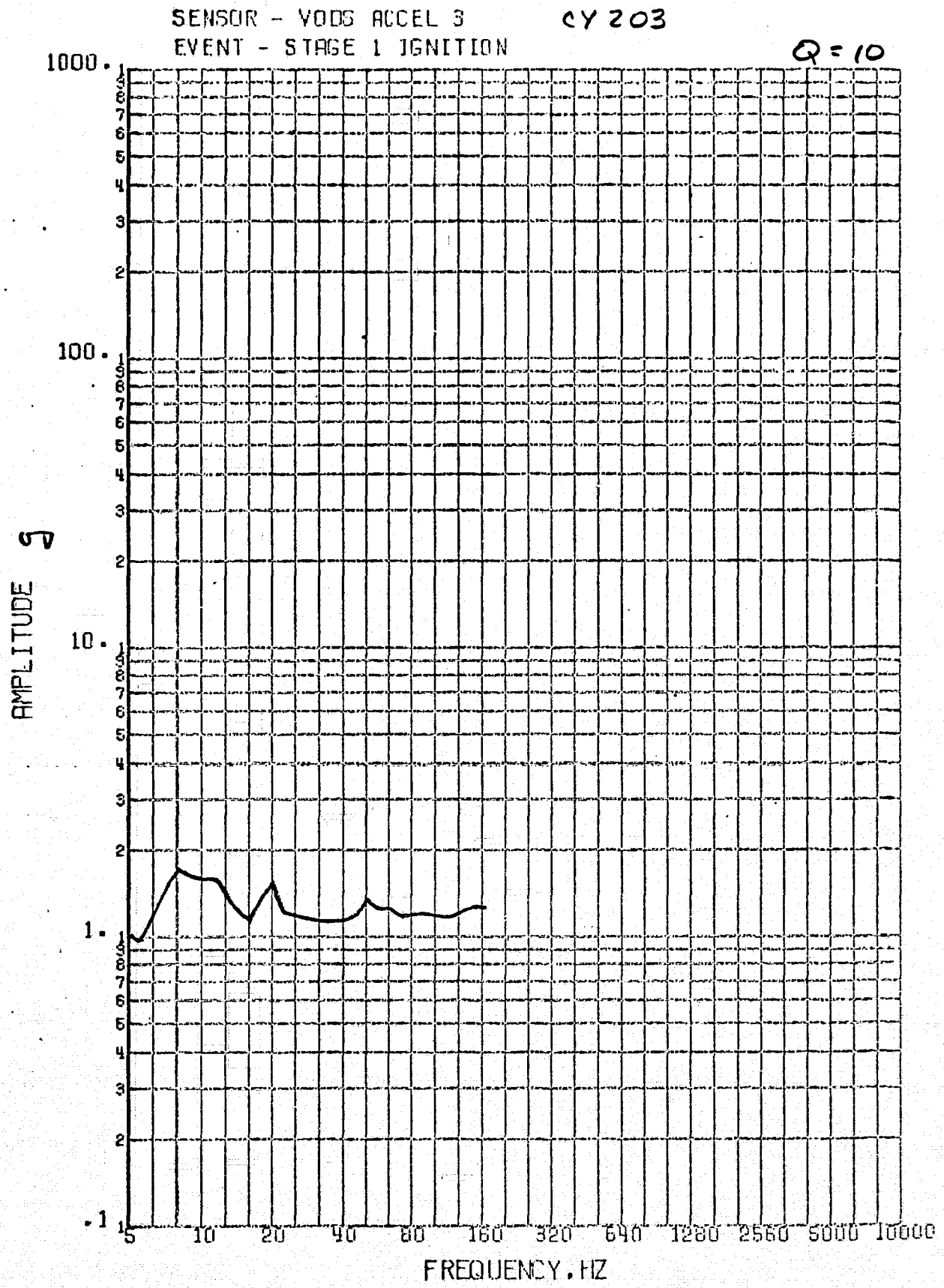
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Figure 6a



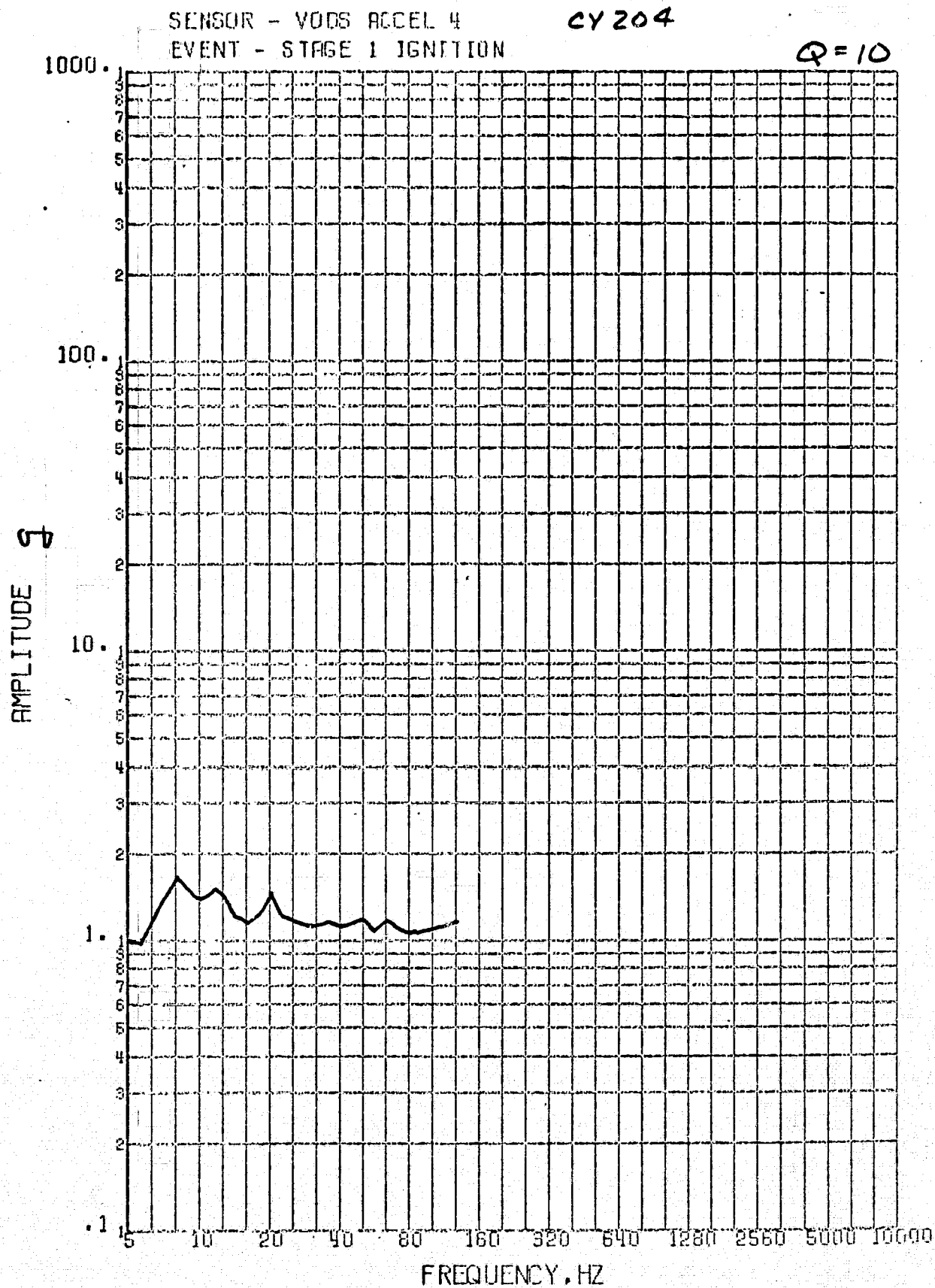
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Figure 6 b



2.35

Figure 6 c



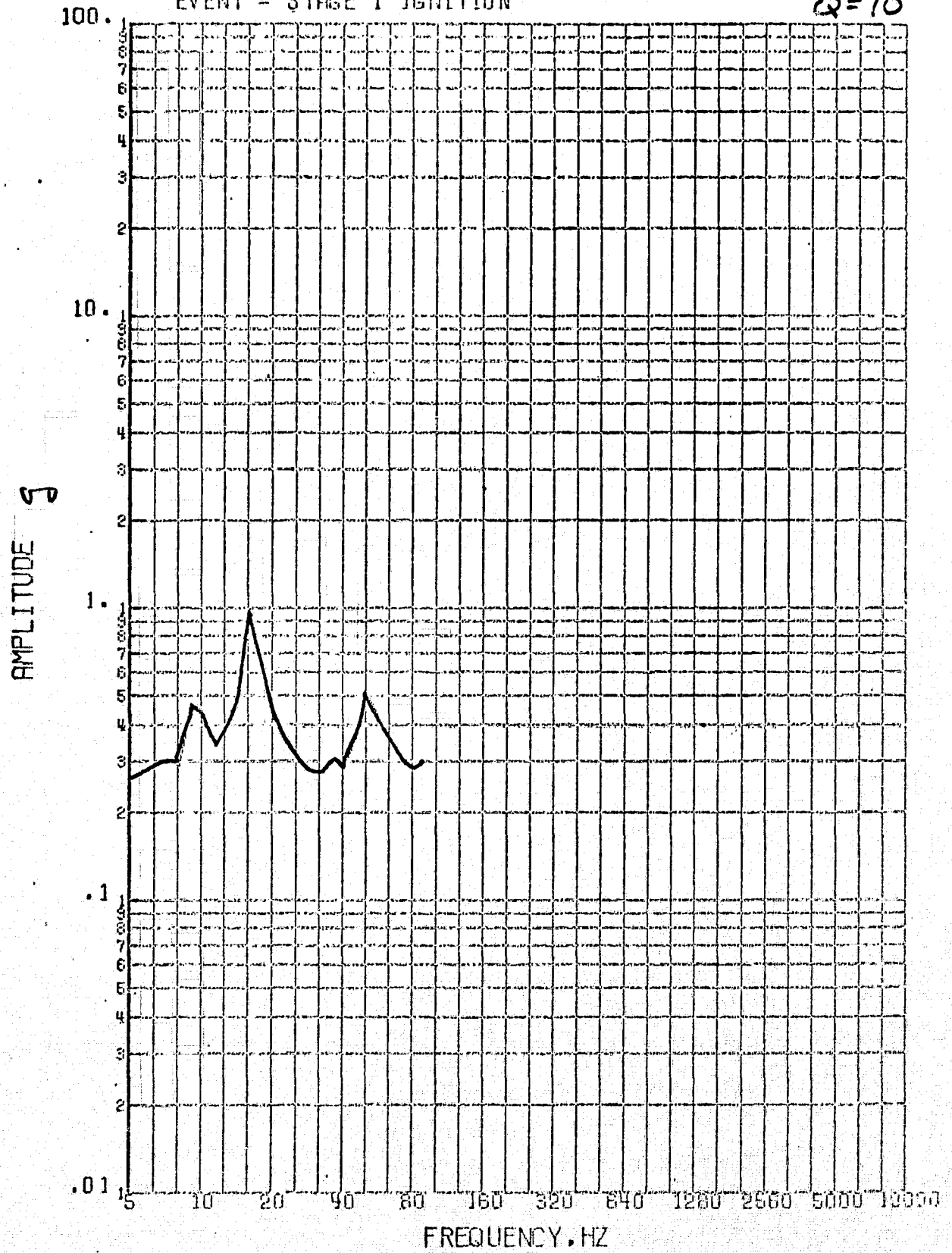
2.36

Figure 6 d

SENSOR - VOIDS ACCEL 5
EVENT - STAGE 1 IGNITION

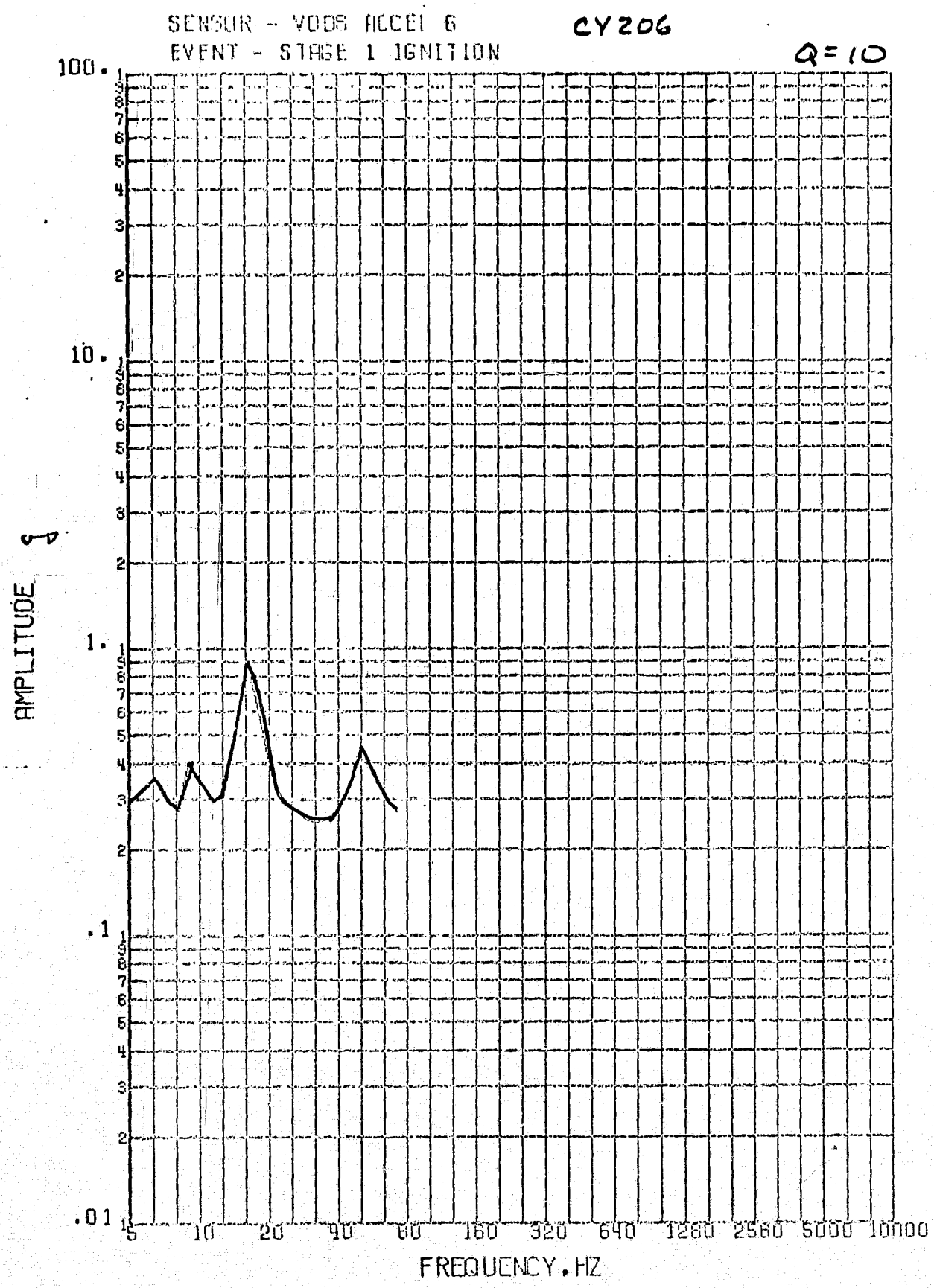
CY 205

Q=10



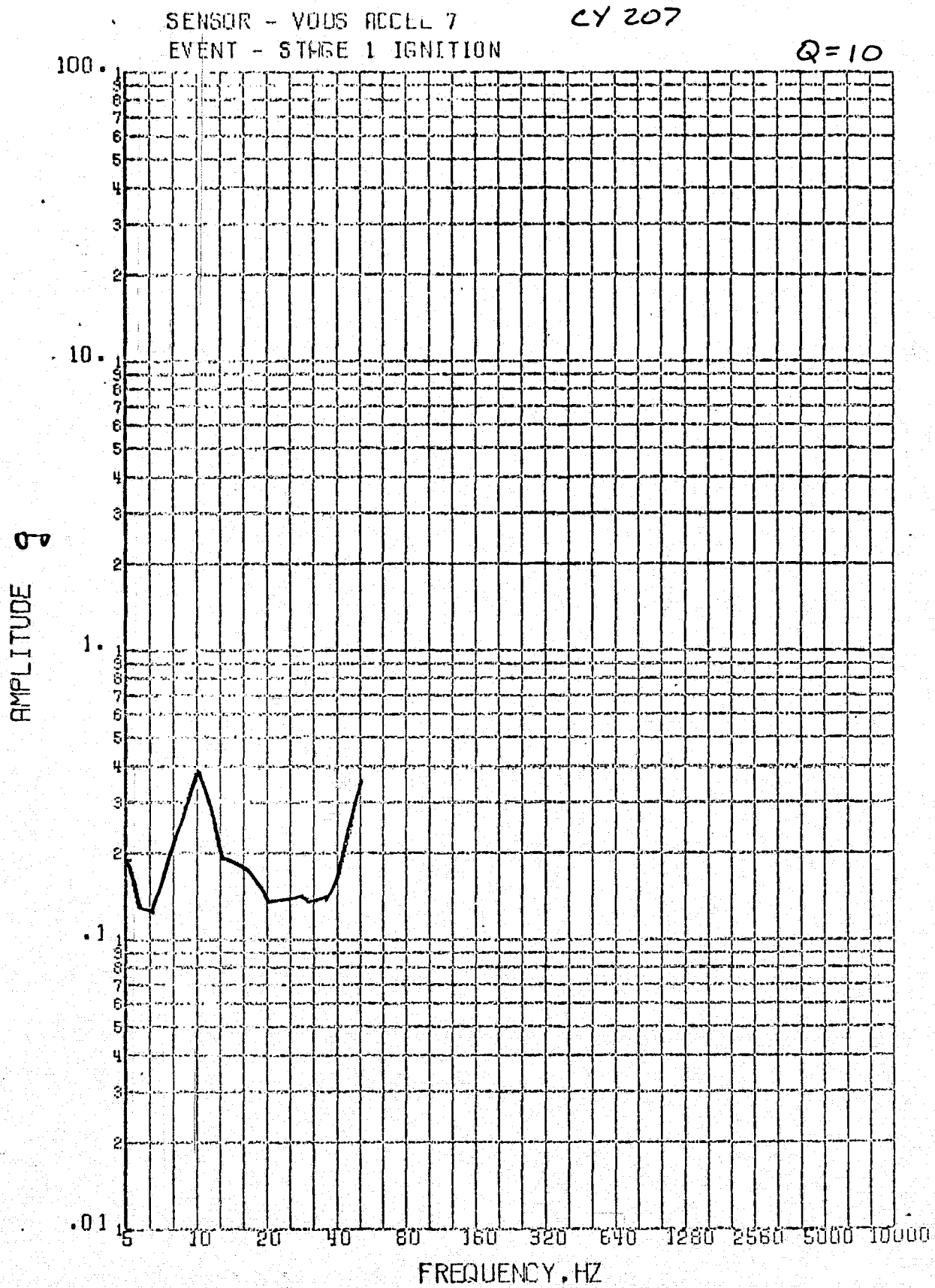
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Figure 6 e



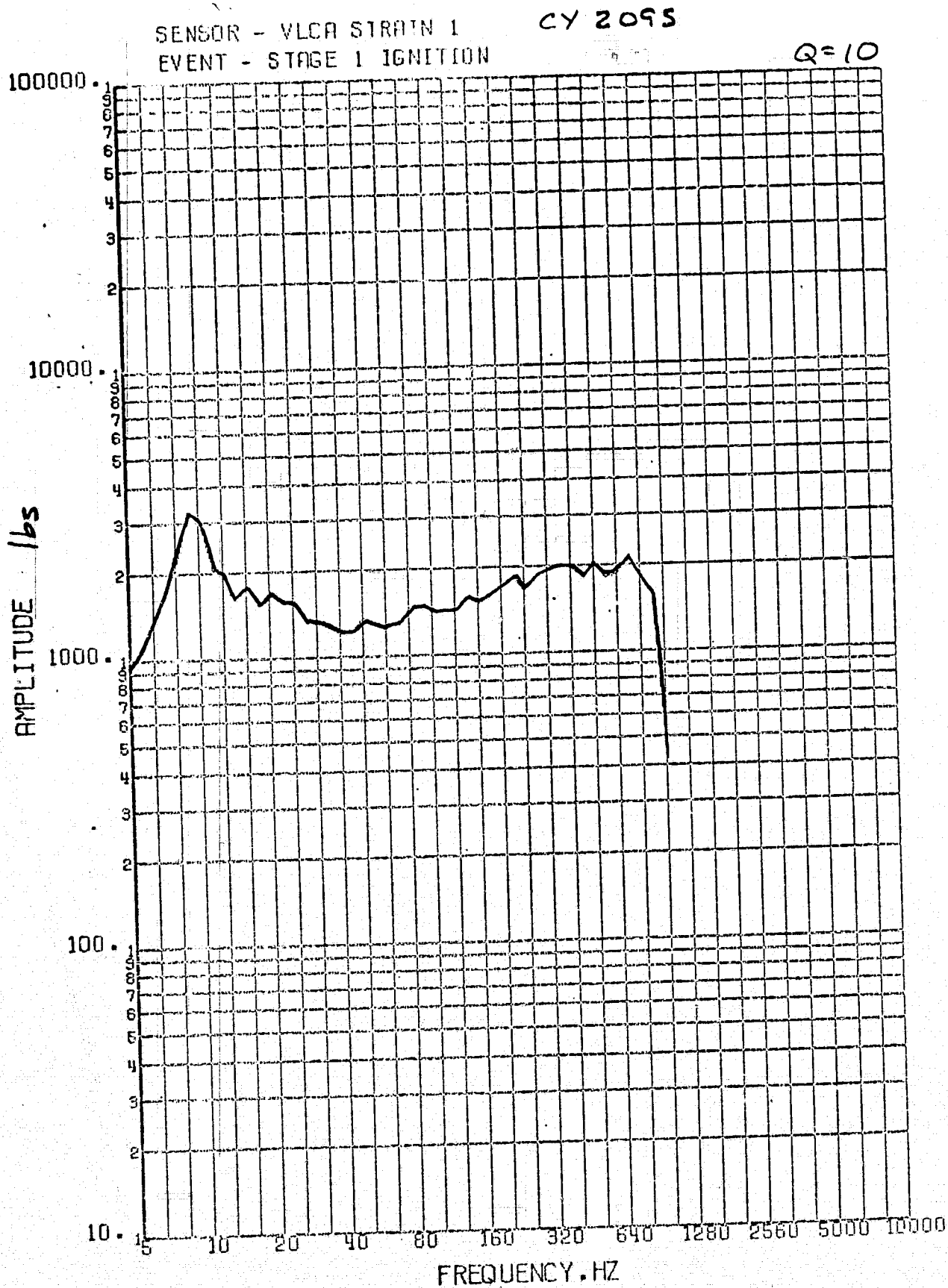
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Figure 6 f



2.39

Figure 6 g



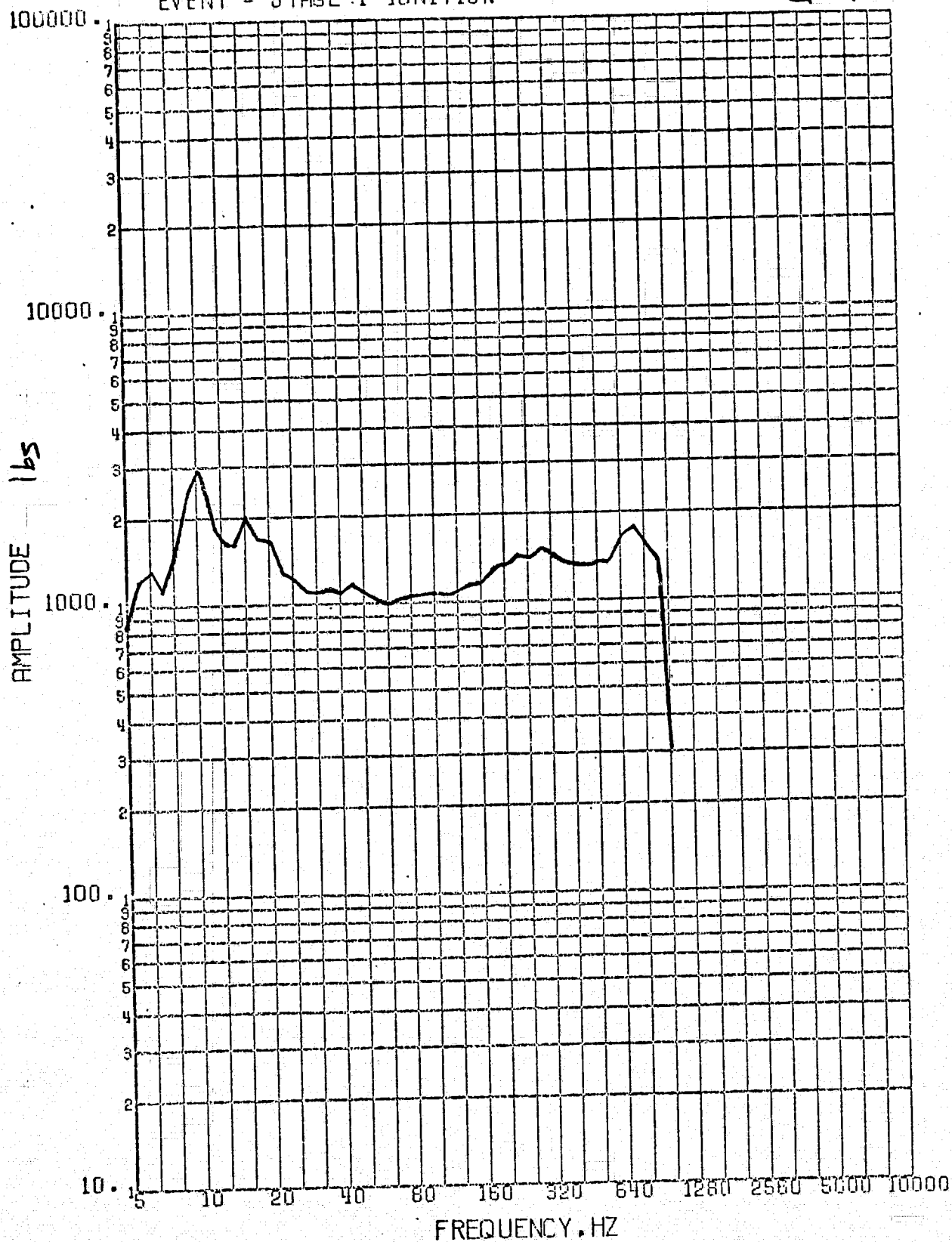
2.40

Figure 6 R

SENSOR - VLCA STRAIN 2
EVENT - STAGE 1 IGNITION

2Y2105

Q=10



2.41

Figure 6 j

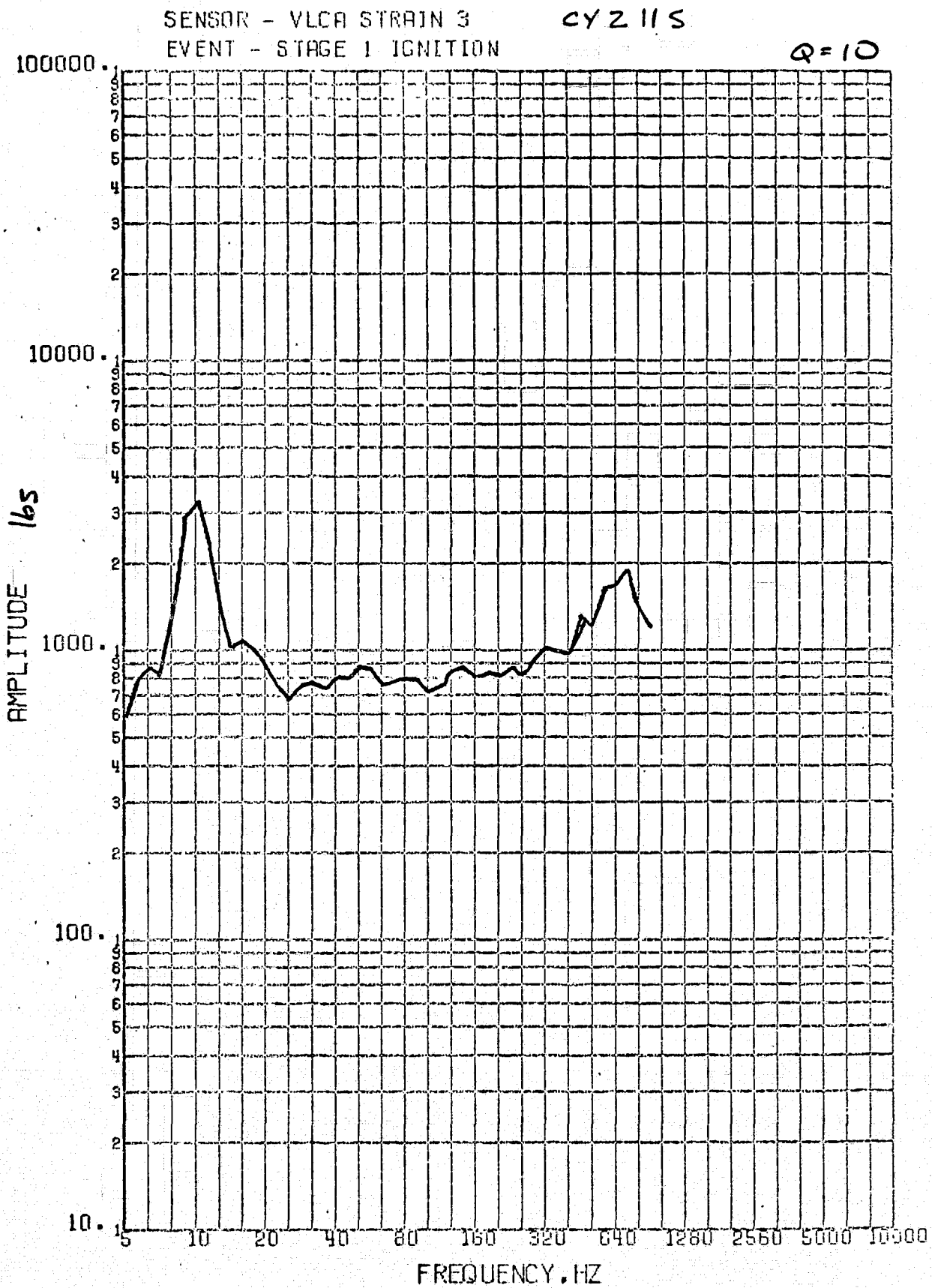


Figure 6 k

SENSOR - VLCA STRAIN 4
EVENT - STAGE 1 IGNITION

CY 212 S

Q = 10

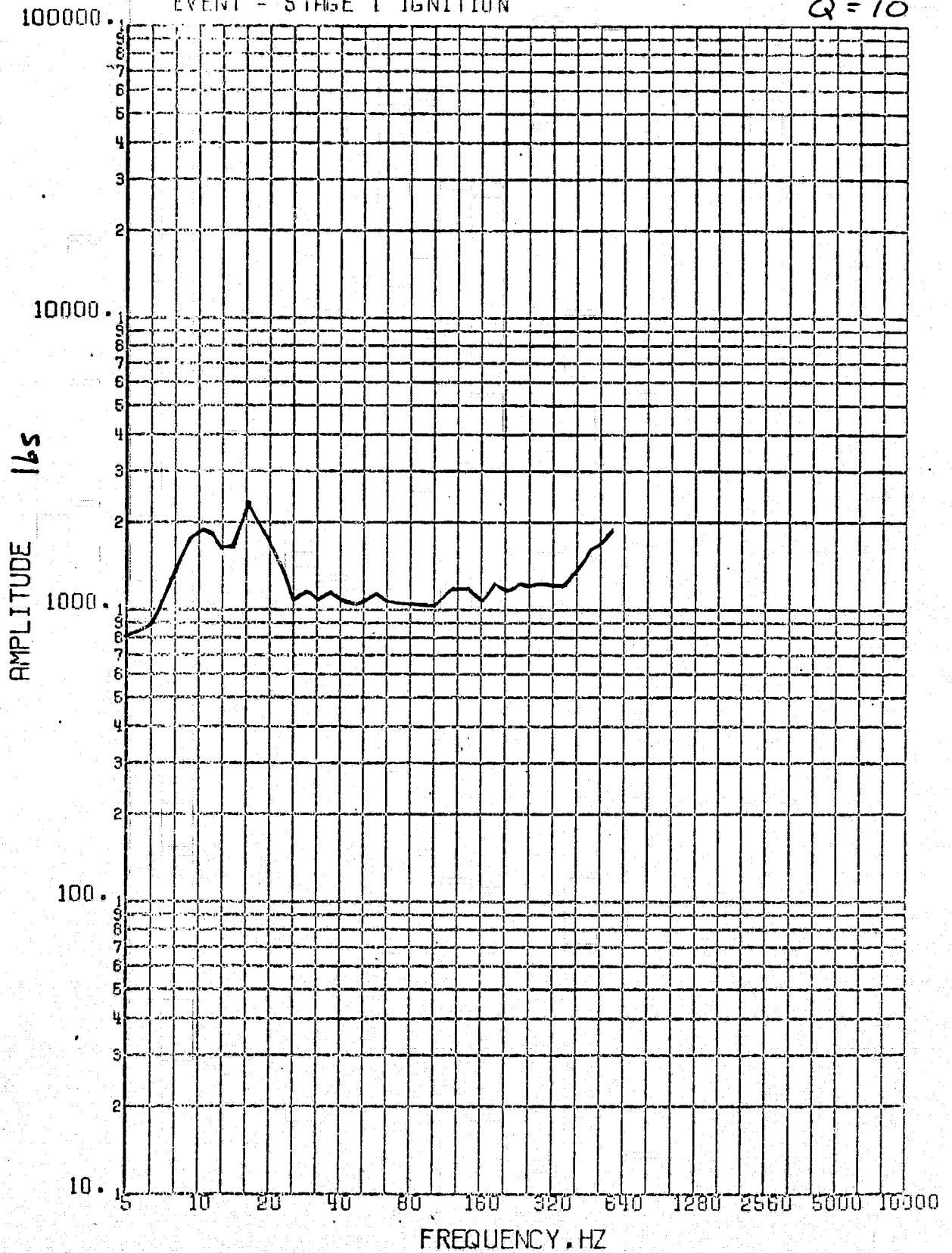
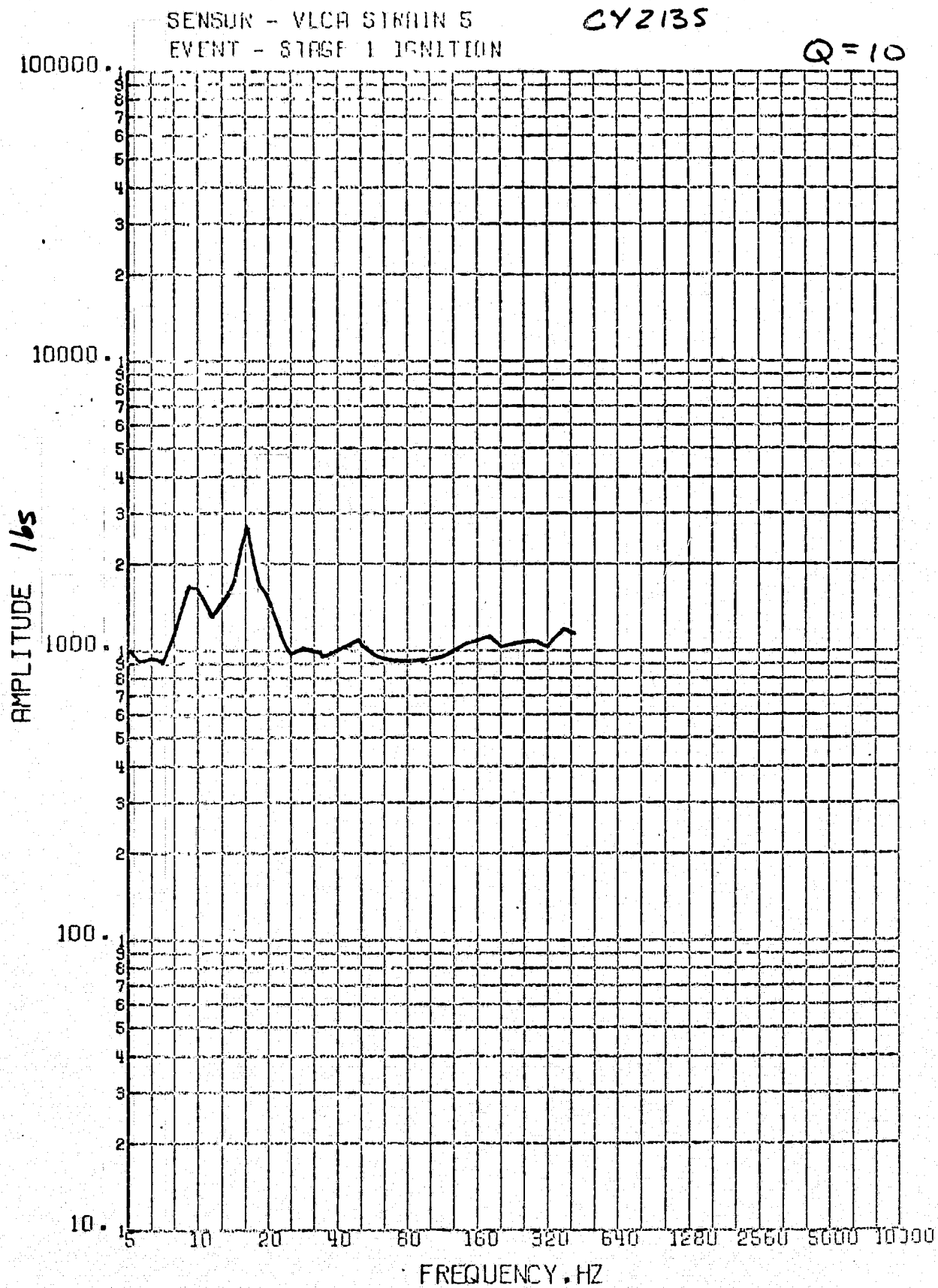


Figure 6 e



2.44

Figure 6 m

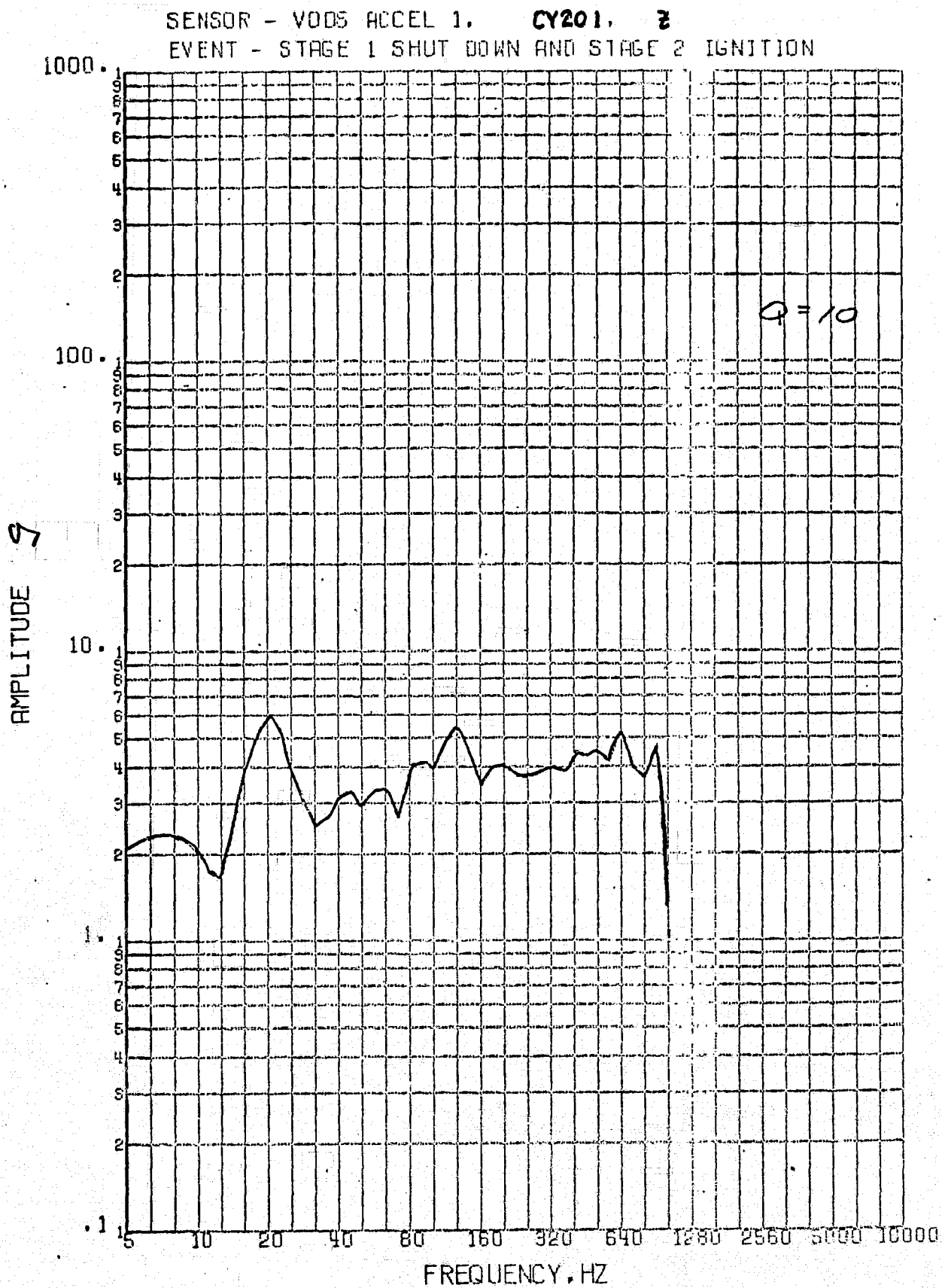


Figure 7a

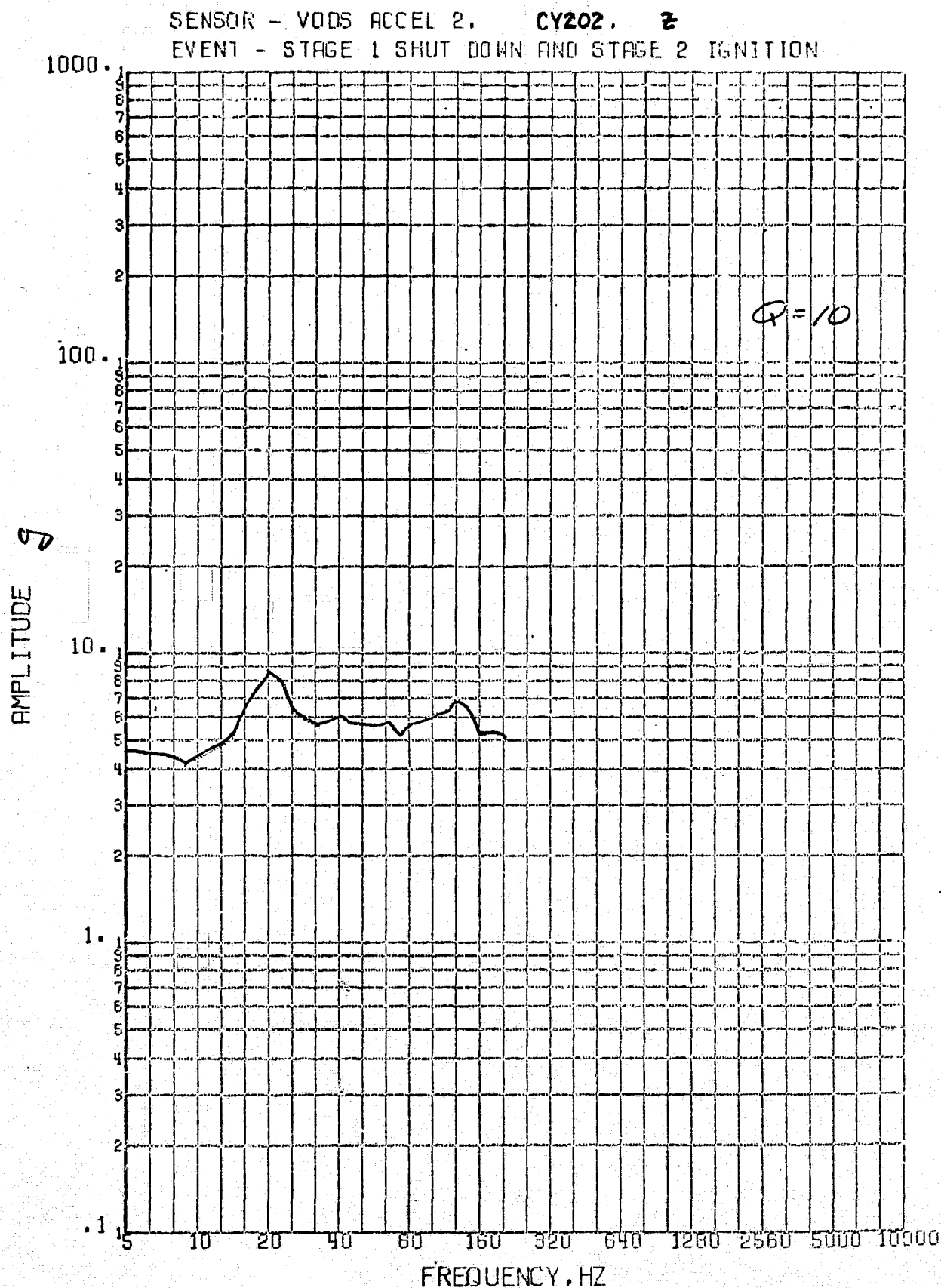


Figure 7 b

SENSOR - VDDS ACCEL 3, CY203, 2
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

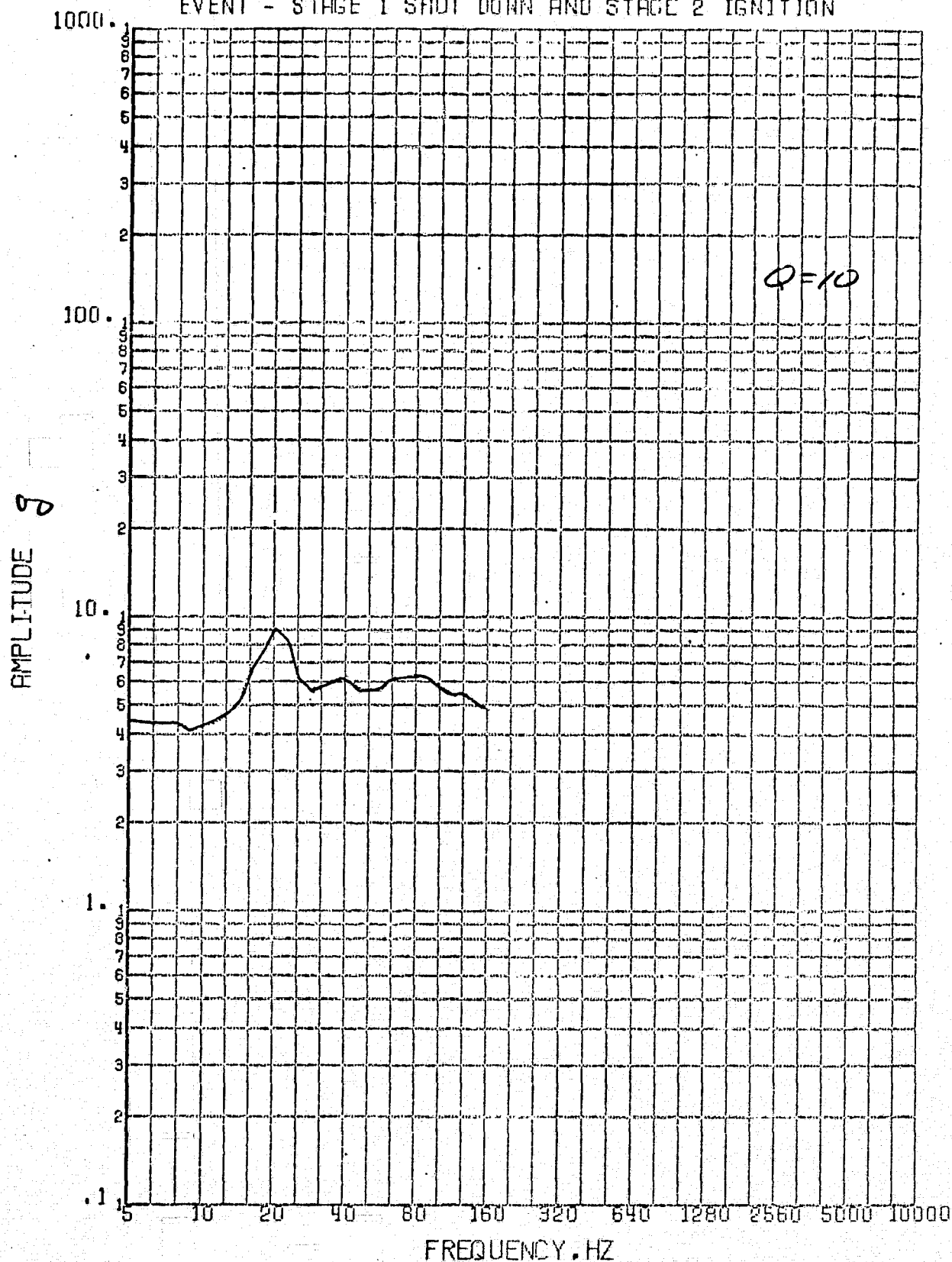


Figure 7c

4-9-74

SENSOR - VDDS ACCEL 4. CY204. 2
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

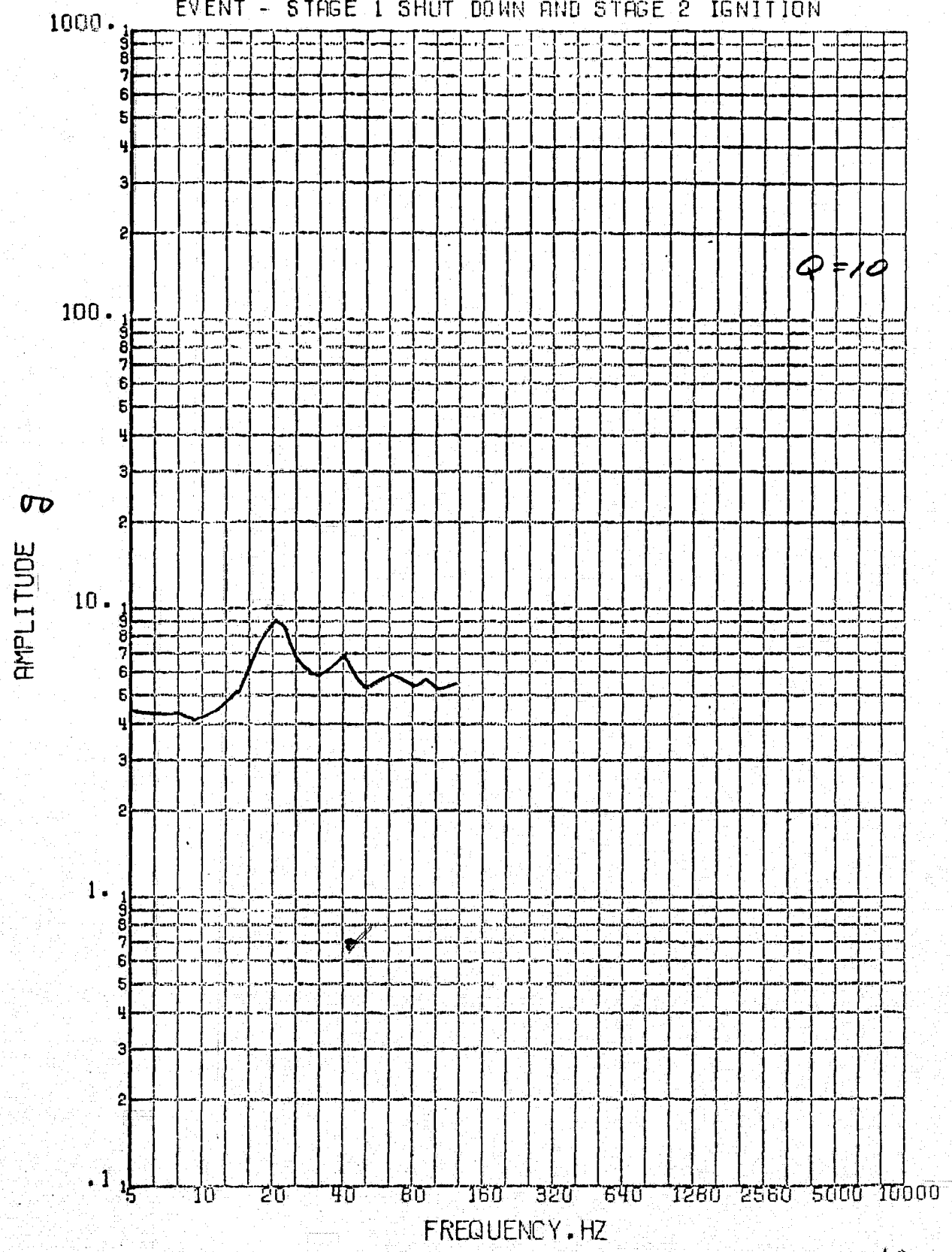


Figure 7 d

SENSOR - VDDS ACCEL 5. CY205. Y
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

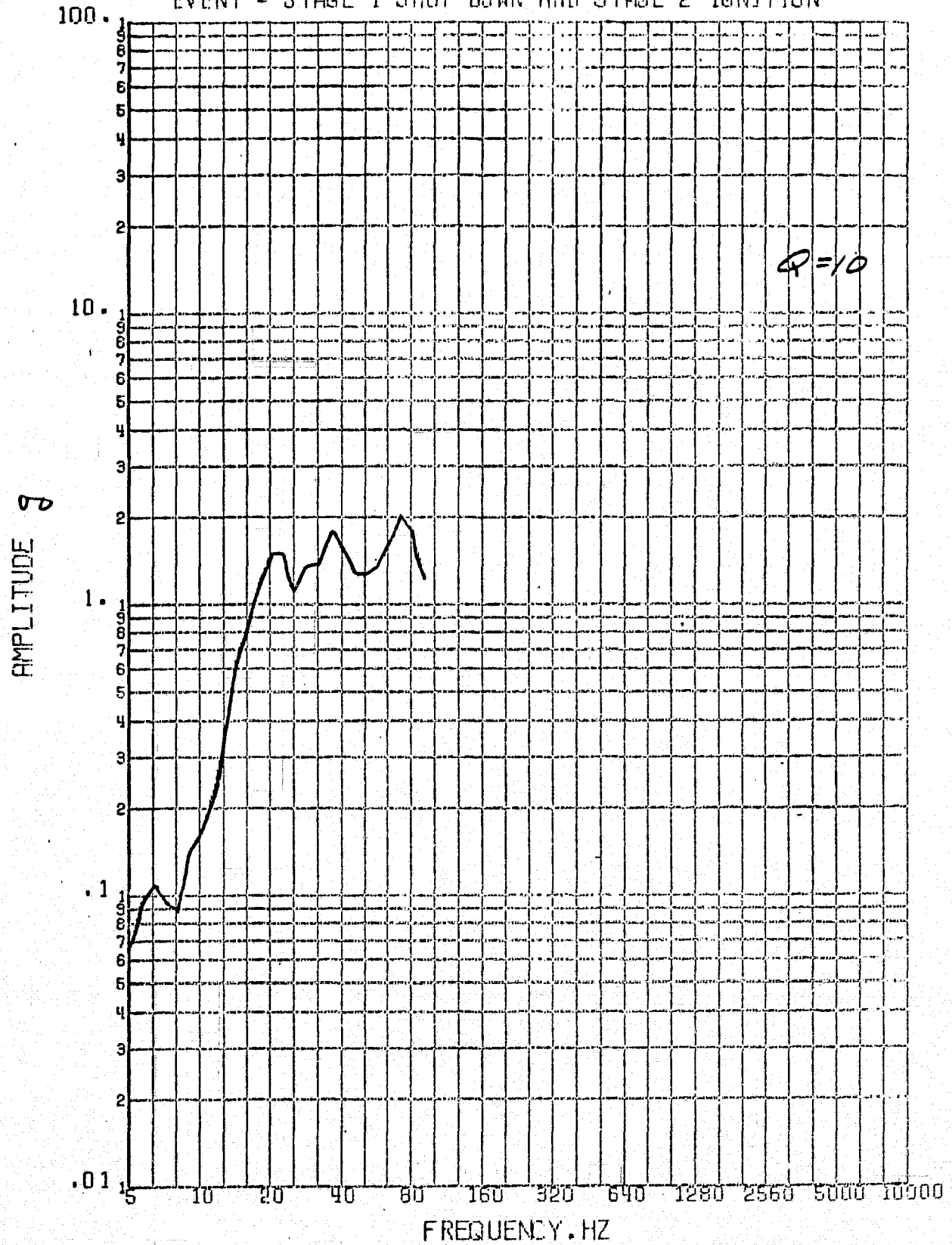


Figure 7e

SENSOR - VOOS ACCEL 6. CY206. Y
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

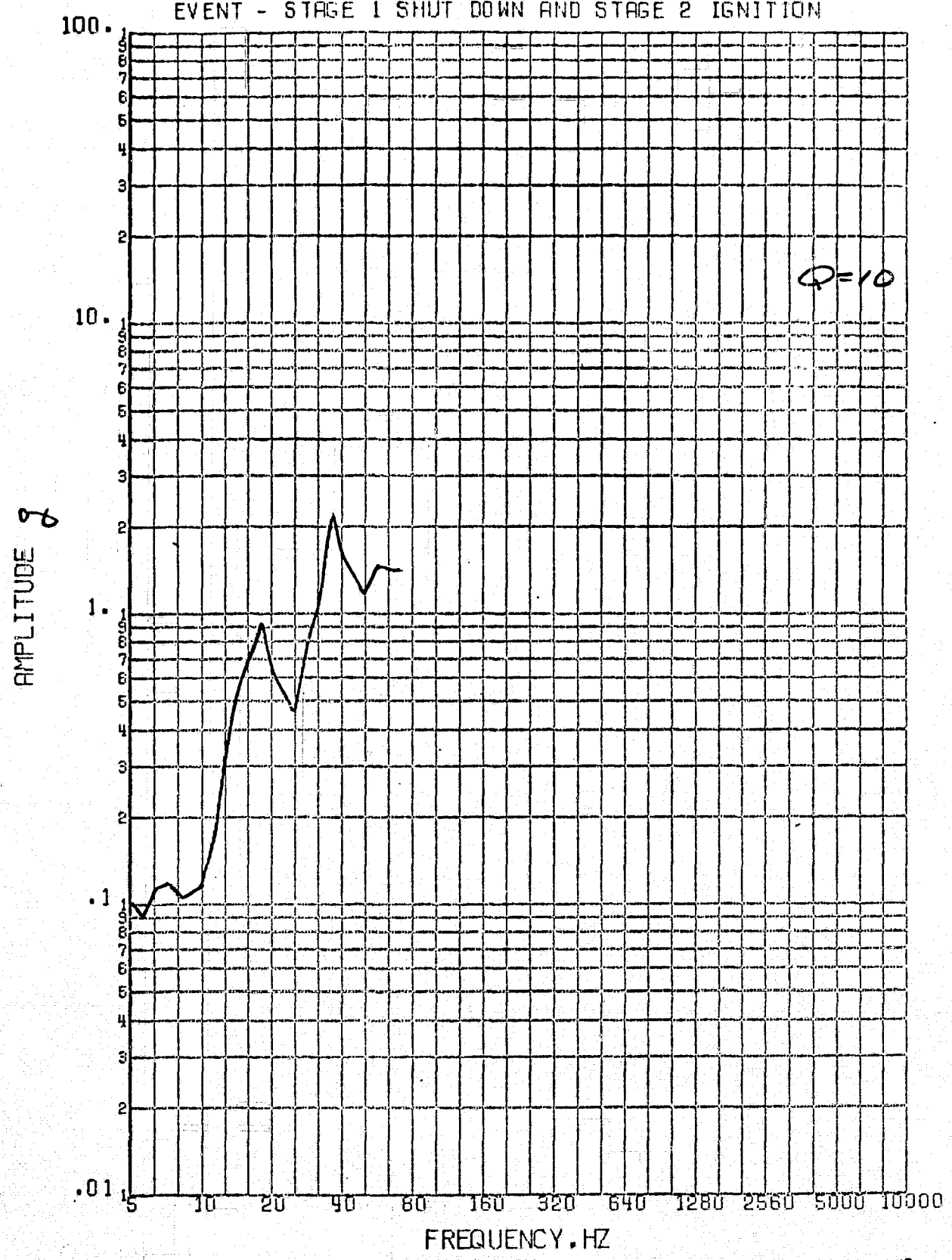


Figure 7 f.

REVISION A
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SENSOR - VOOS ACCEL 7. CY207. X
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

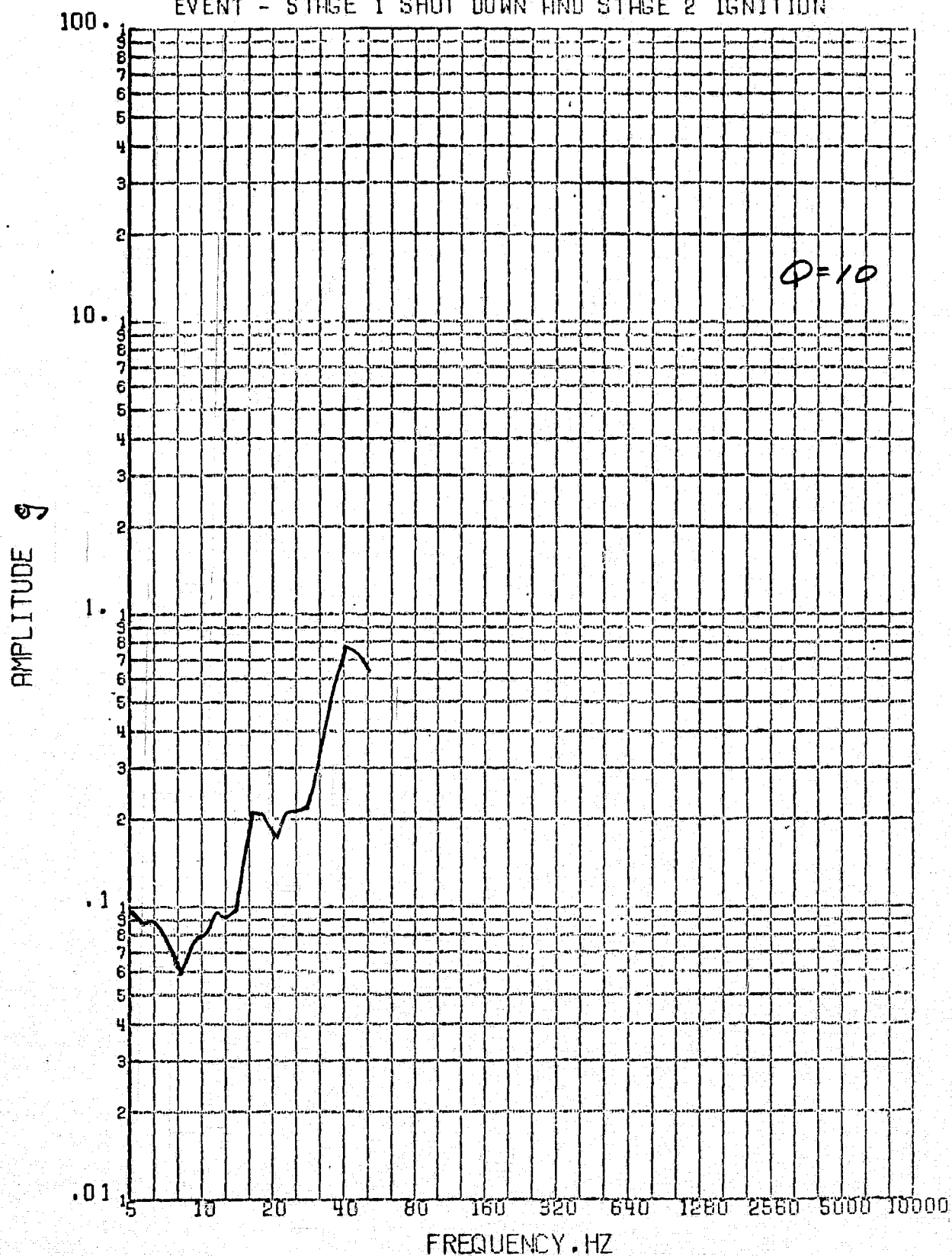


Figure 7g

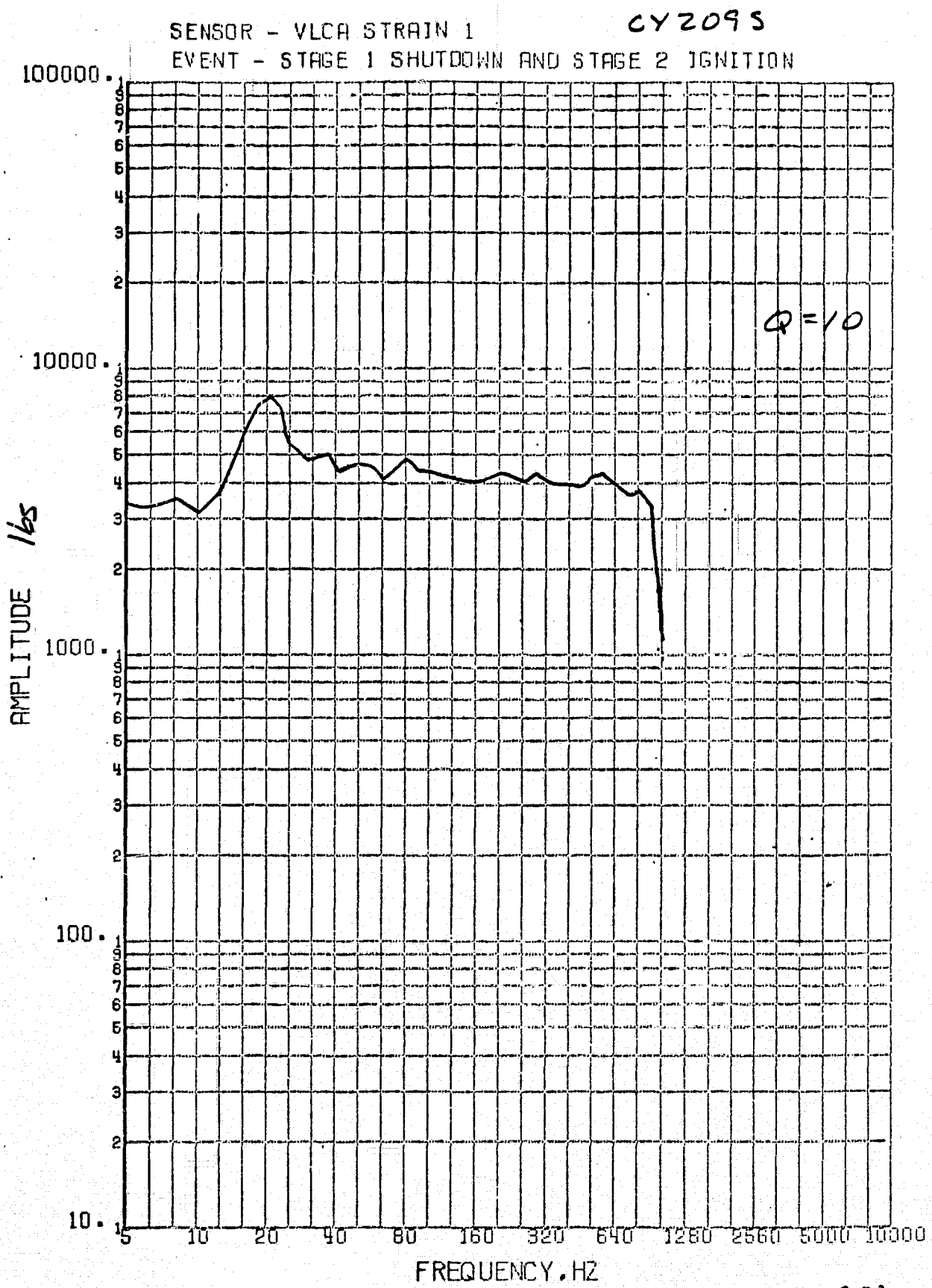


Figure 7h

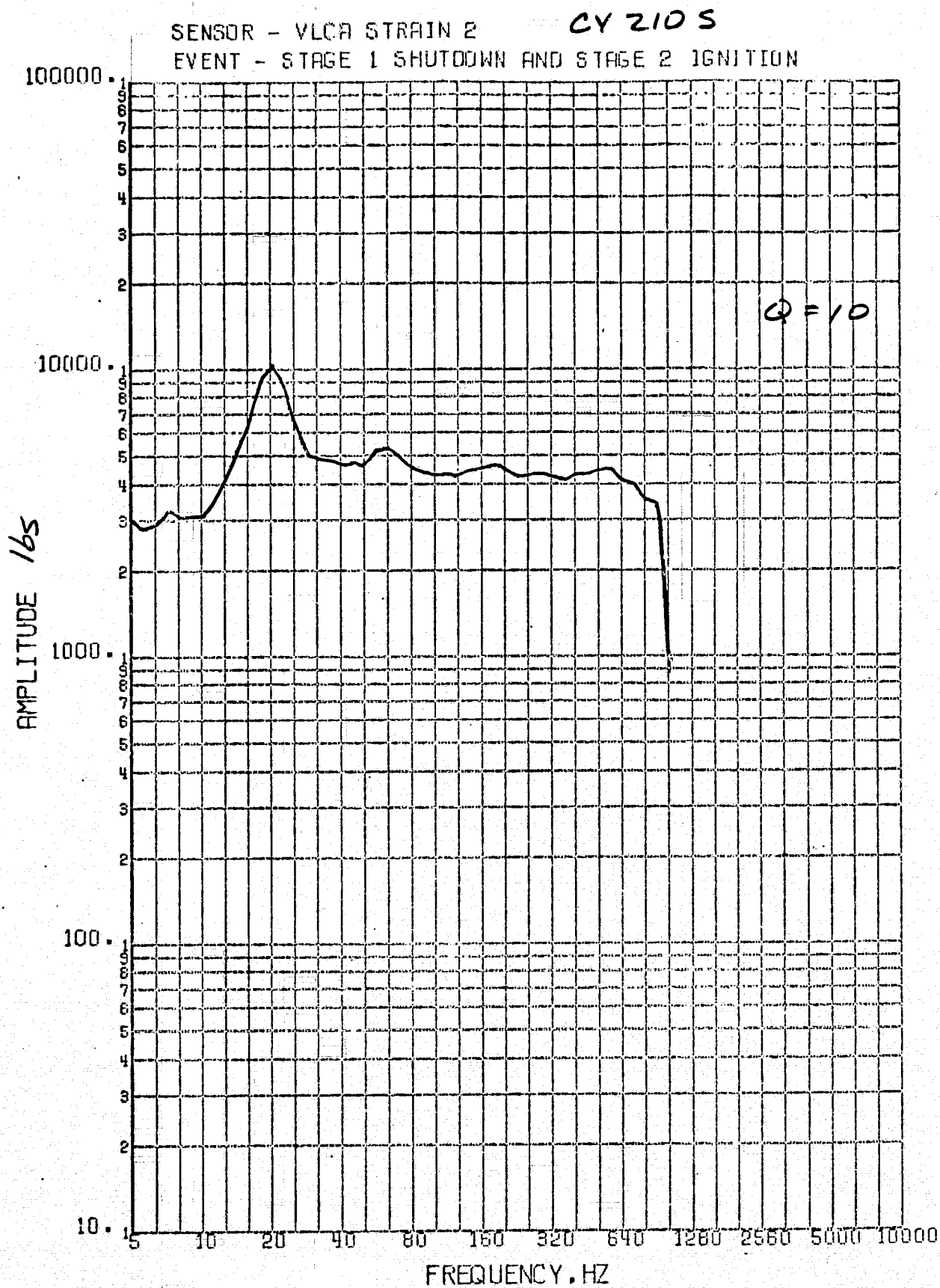


Figure 7 f

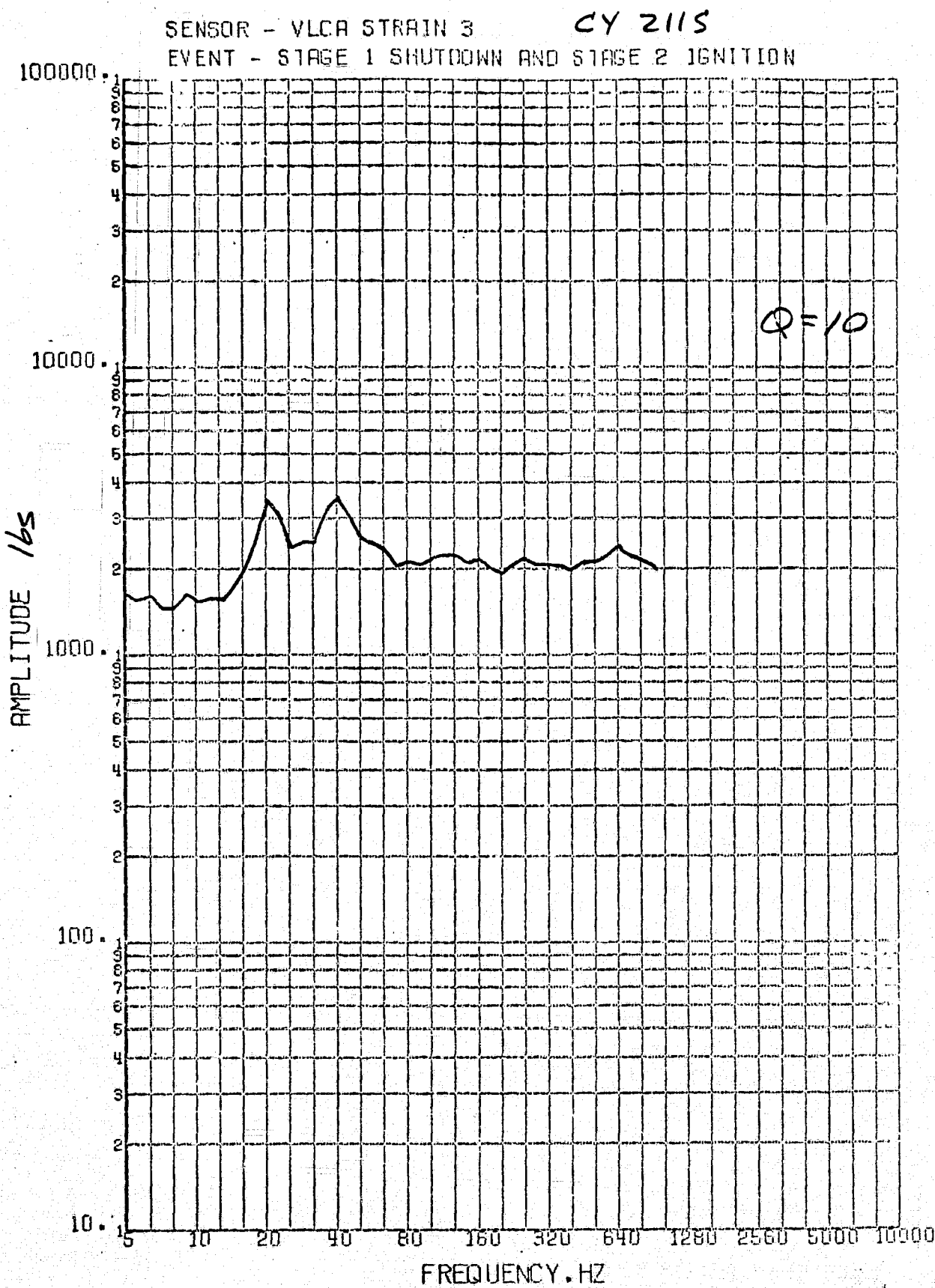


Figure 7k

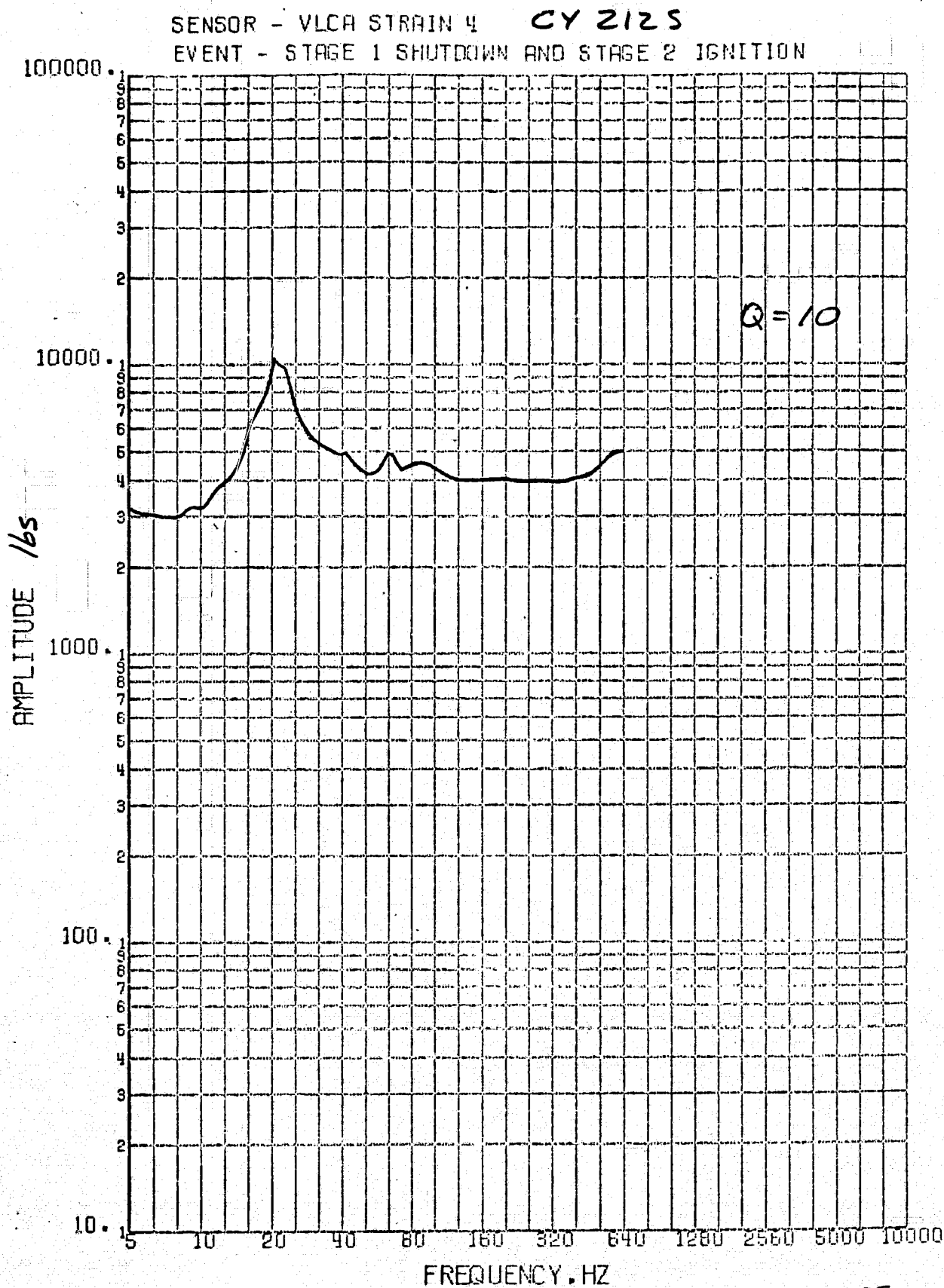
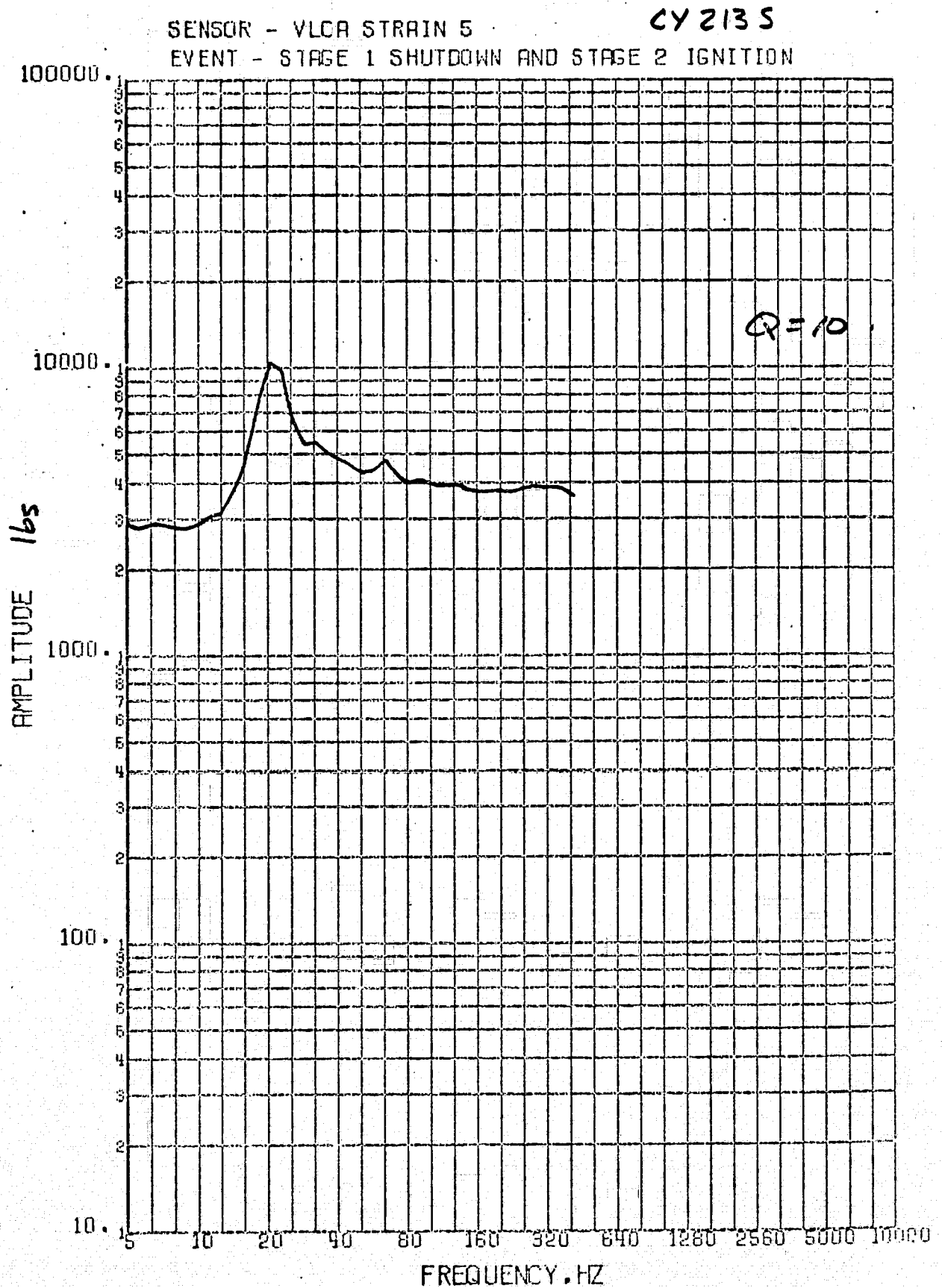


Figure 7e



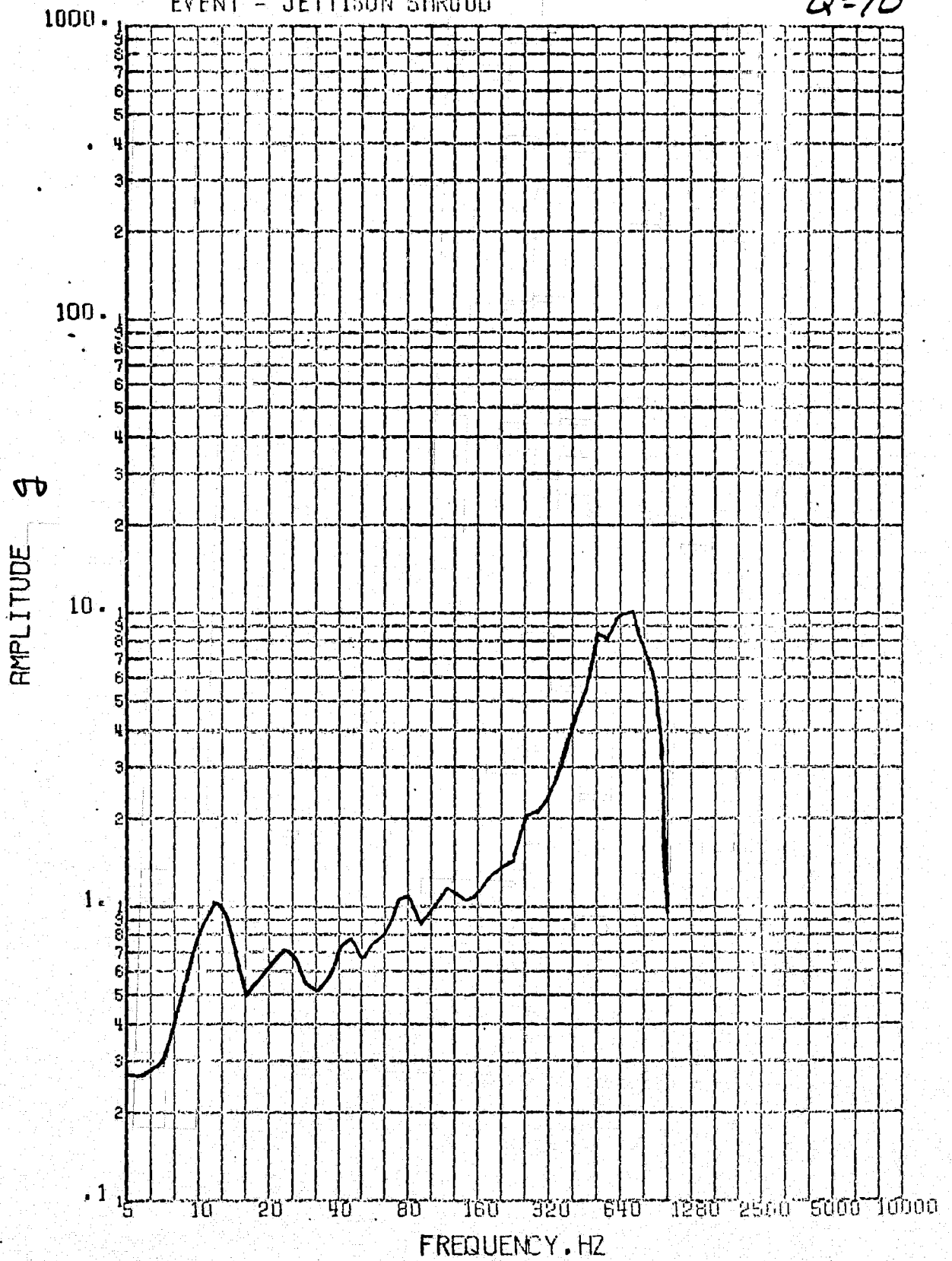
2.56

Figure 7 m

SENSOR - VODS ACCEL 1
EVENT - JETTISON SHROUD

CY 201

Q=10



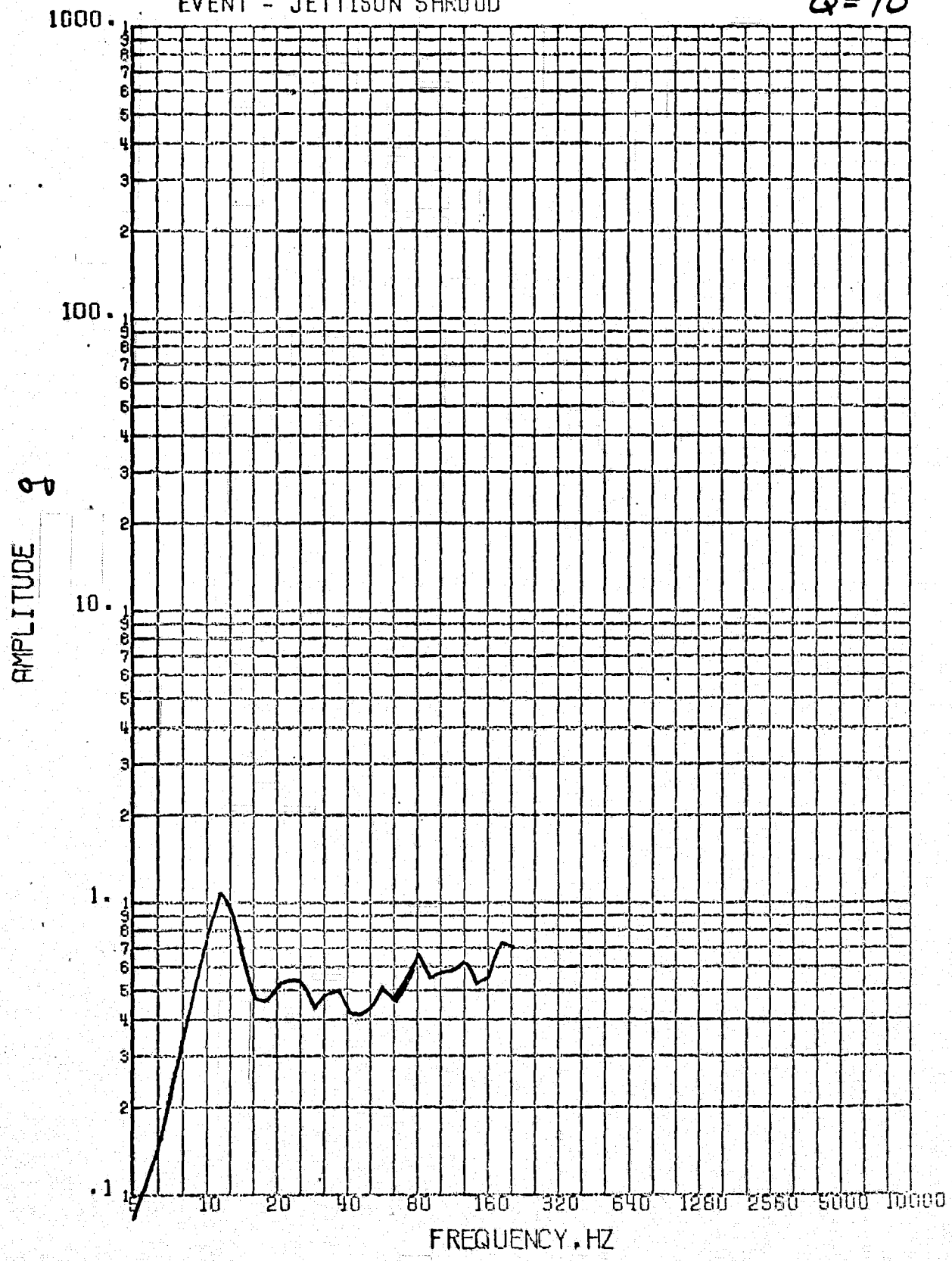
2.57

Figure 8a

SENSOR - VODS ACCEL 2
EVENT - JETTISON SHROUD

CY202

Q=10



2.58

Figure 8 b

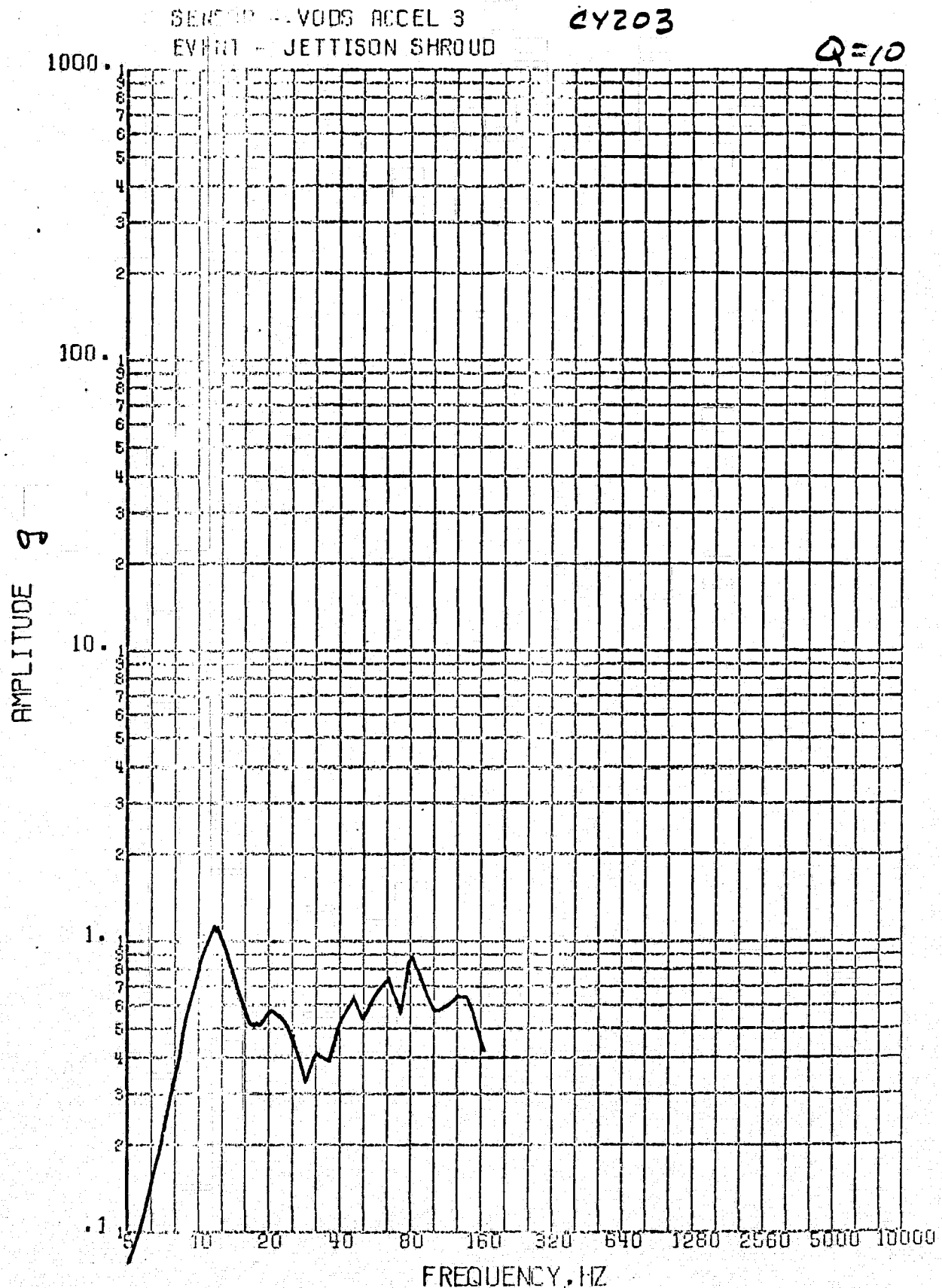


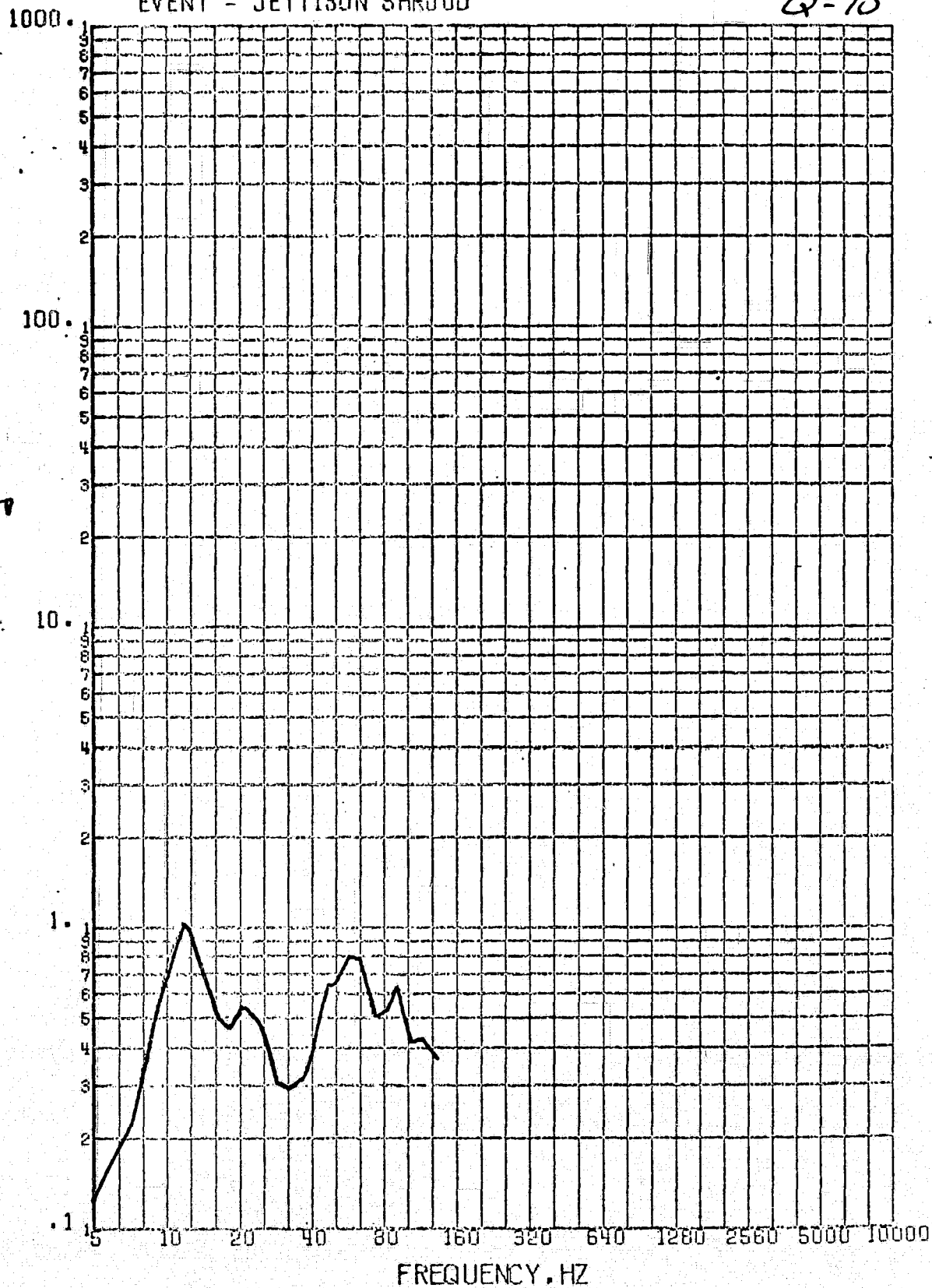
Figure 8 c

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SENSOR - VODS ACCEL 4
EVENT - JETTISON SHROUD

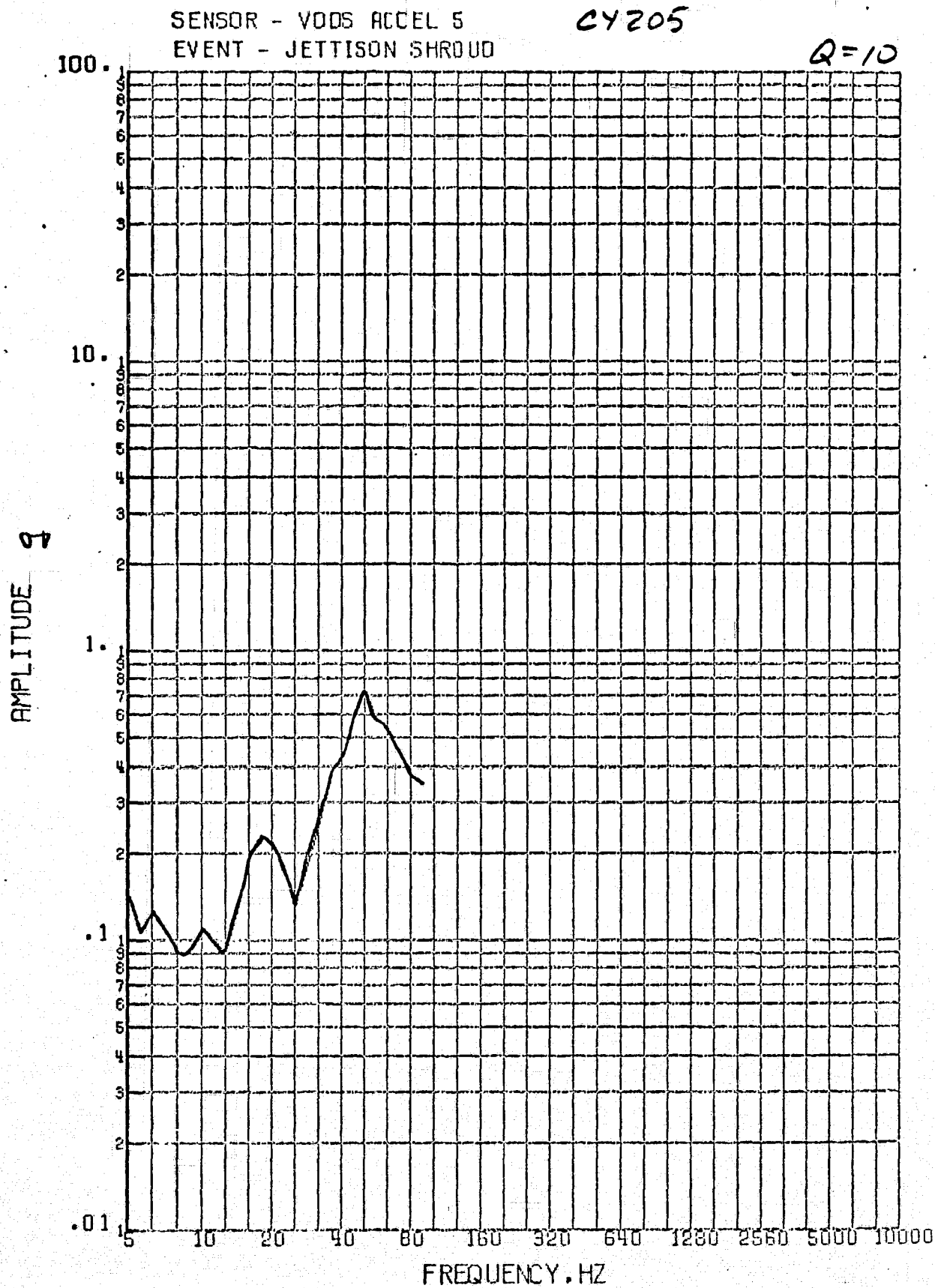
2Y204

Q=10

AMPLITUDE $\frac{1}{g}$ 

2.60

Figure 8 d



2.61

Figure 8 e

SENSOR - VODS ACCEL 6
EVENT - JETTISON SHROUD

CY206

Q=10

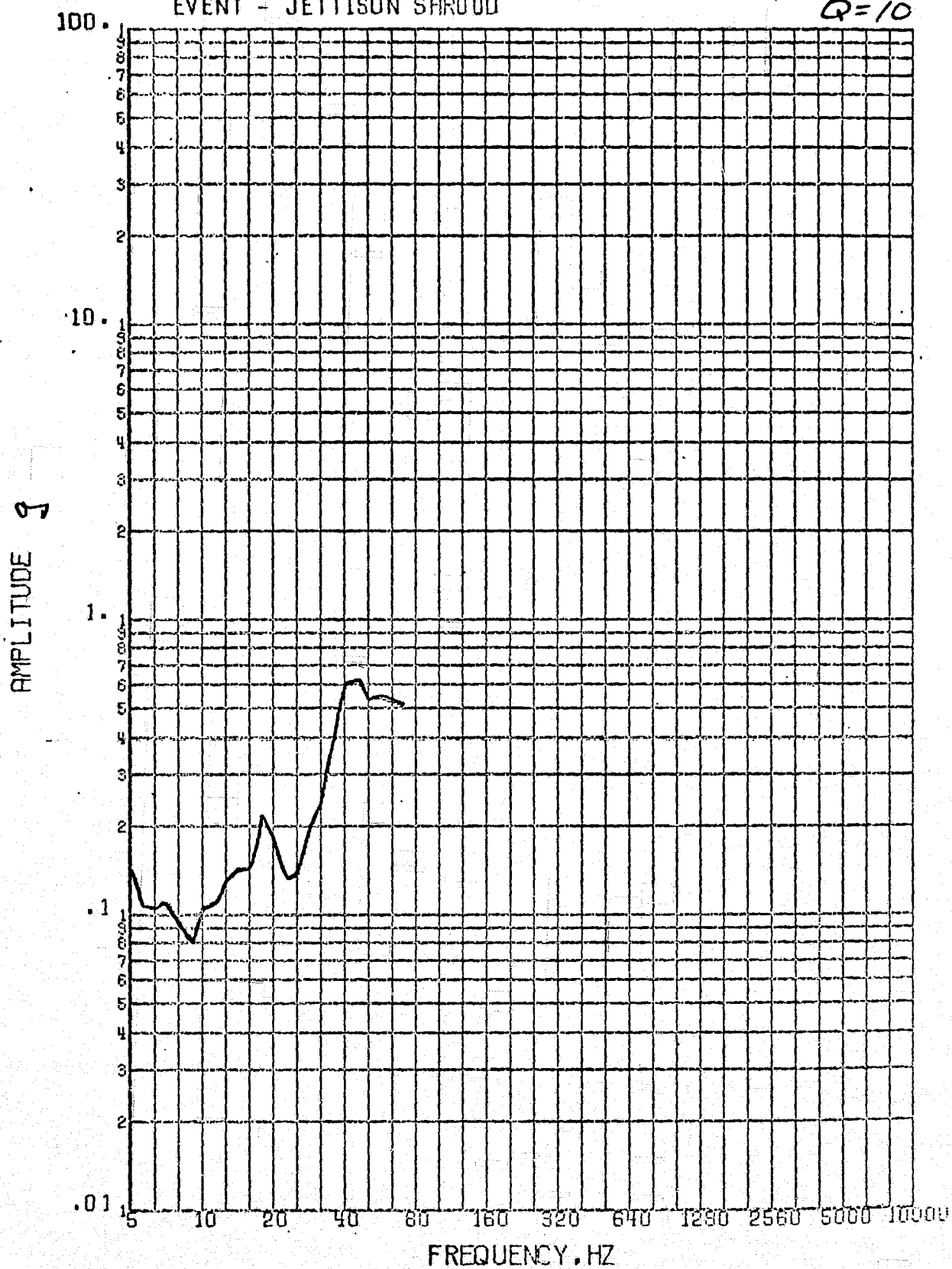


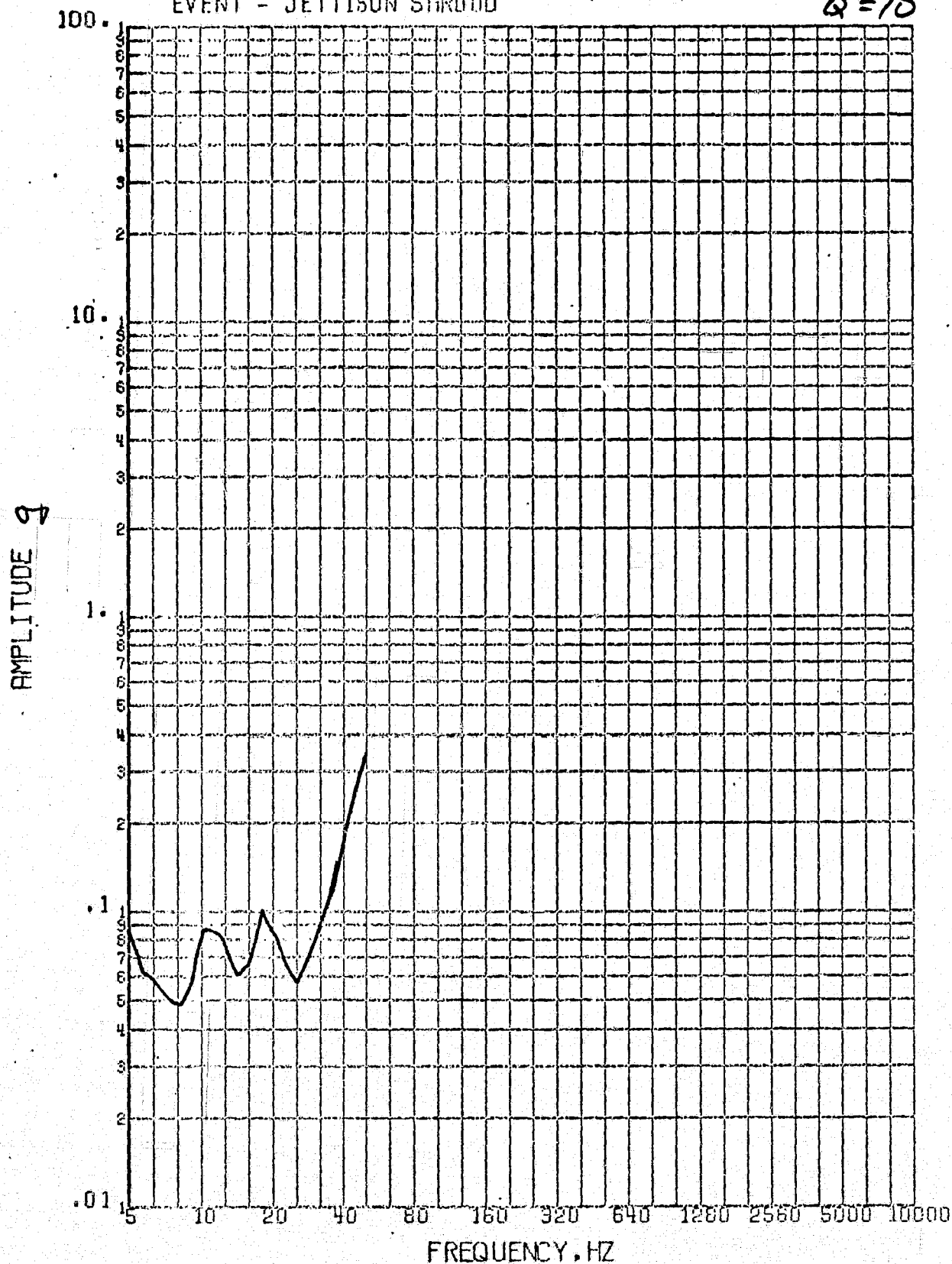
Figure 8 f

2.62

SENSOR - VOOS ACCEL 7
EVENT - JETTISON SHROUD

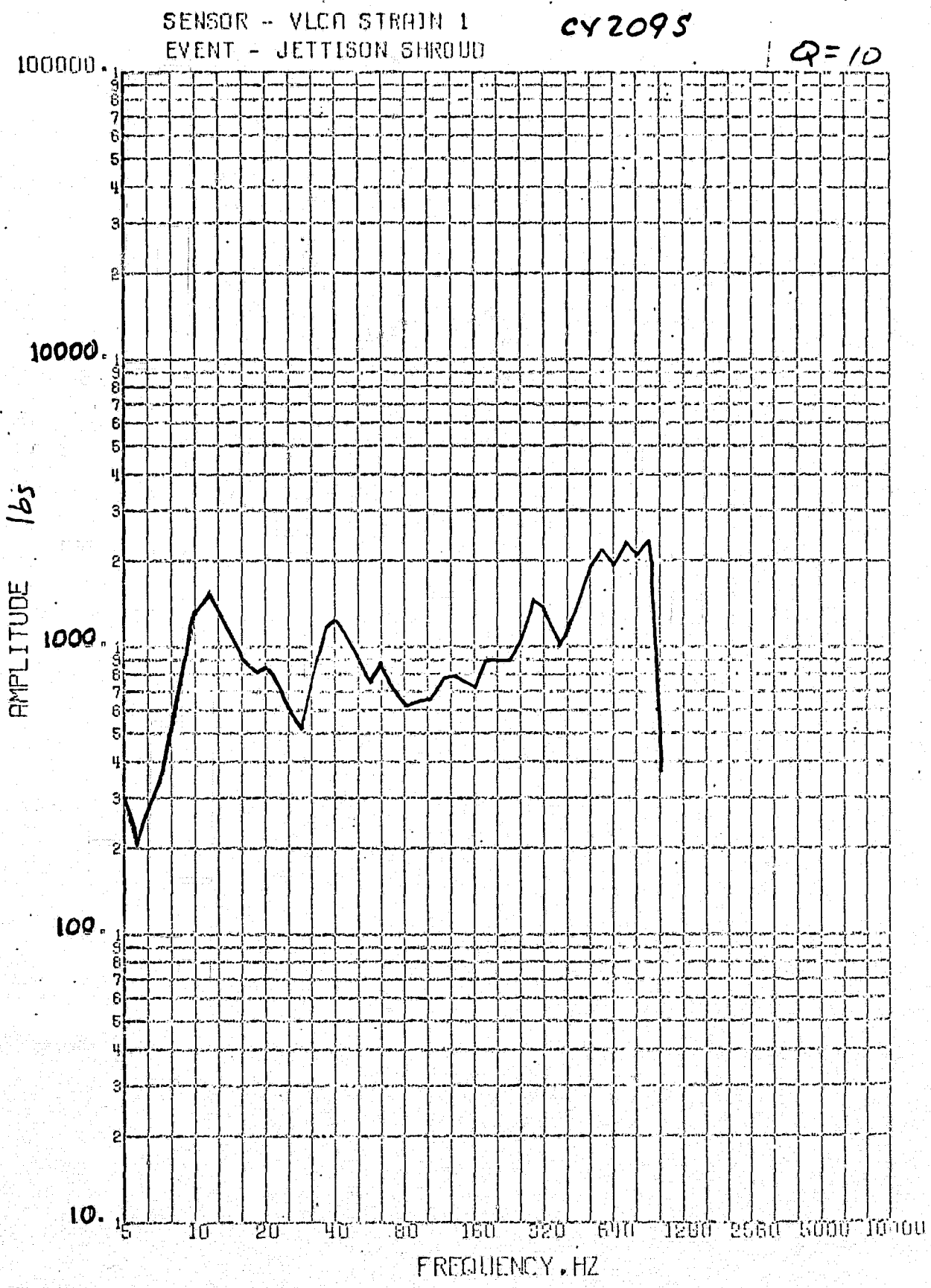
CY207

Q=10



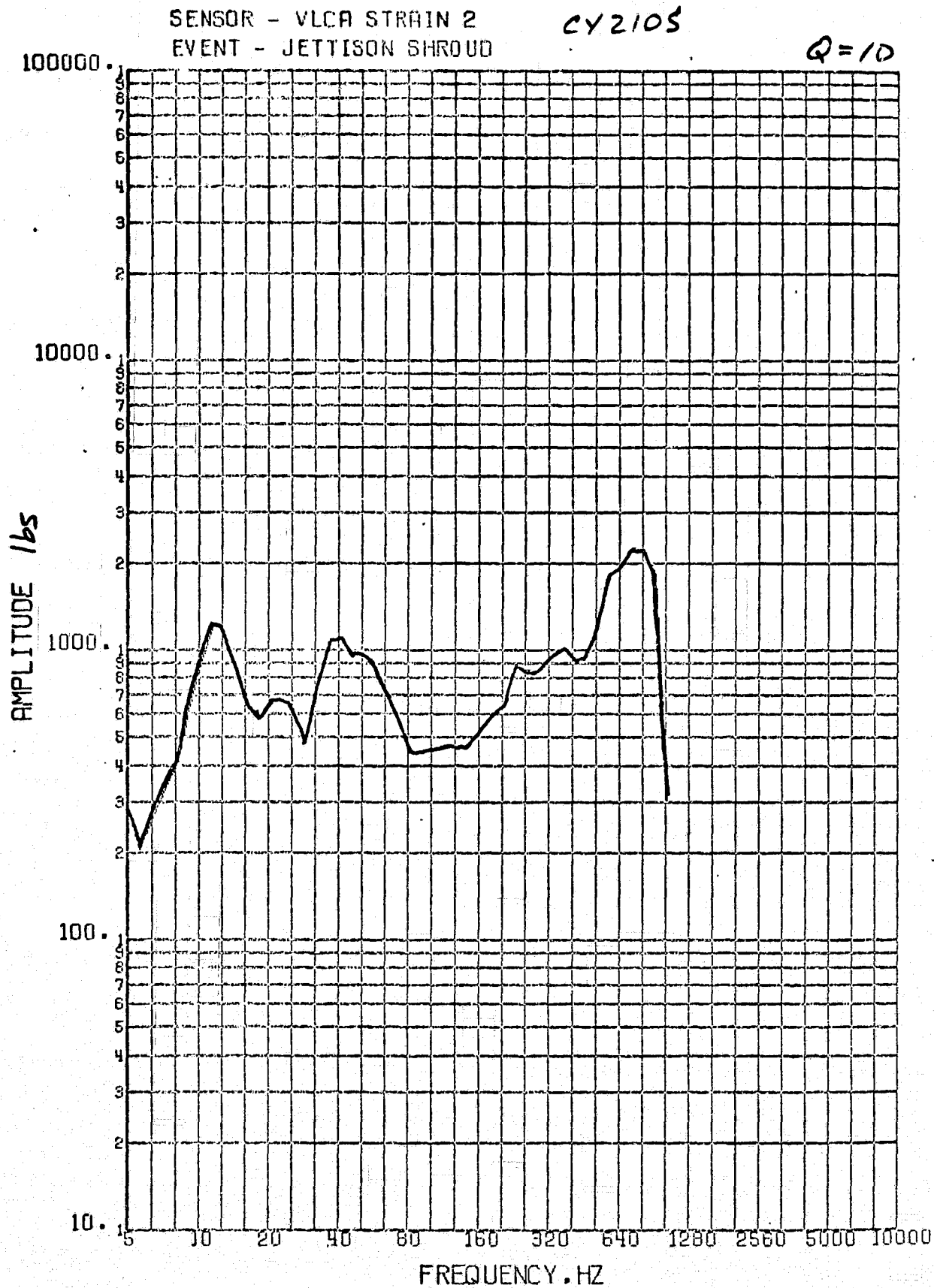
2.63

Figure 8 g



2.64

Figure 8 R



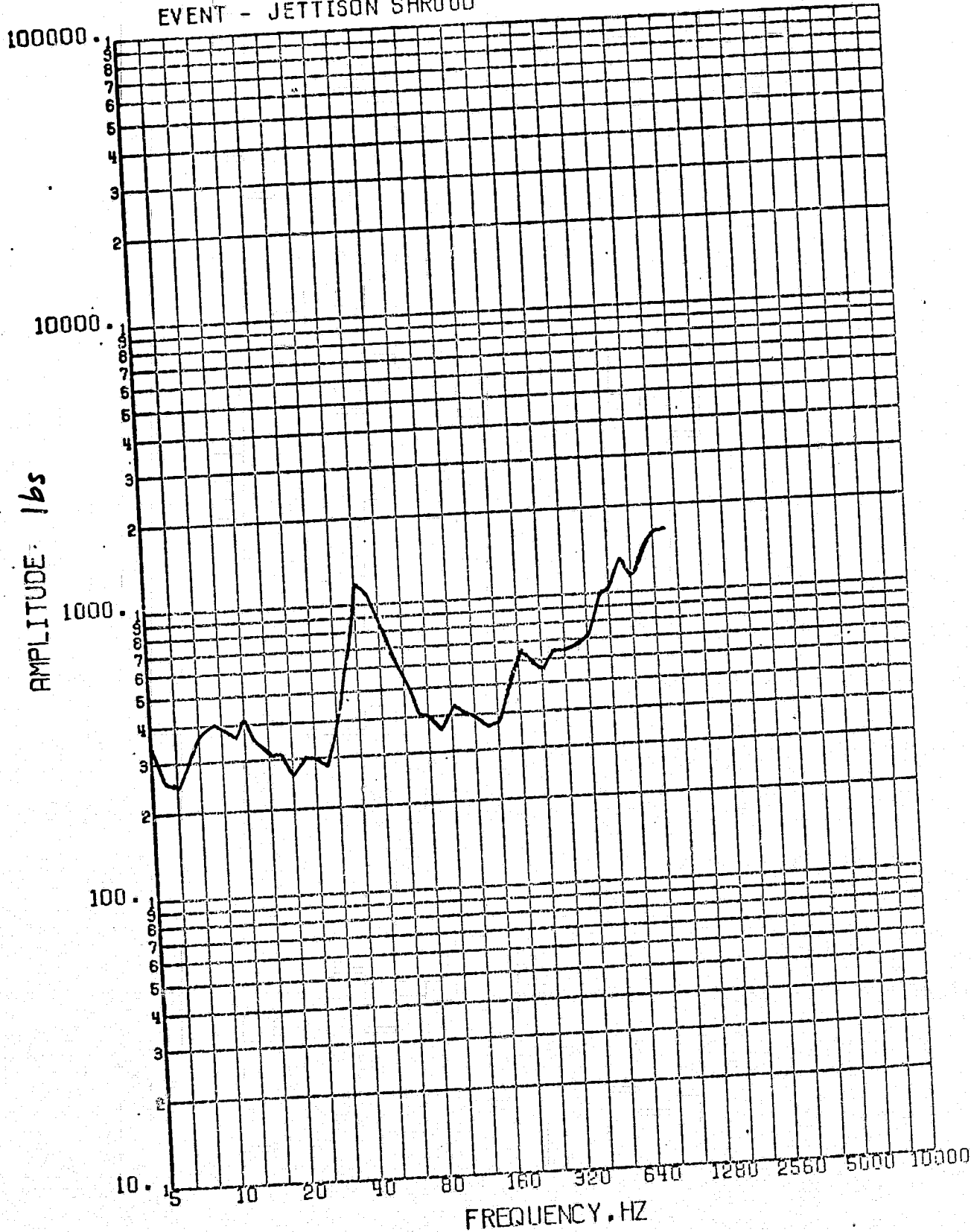
2.65

Figure 8 j

SENSOR - VLCA STRAIN 3
EVENT - JETTISON SHROUD

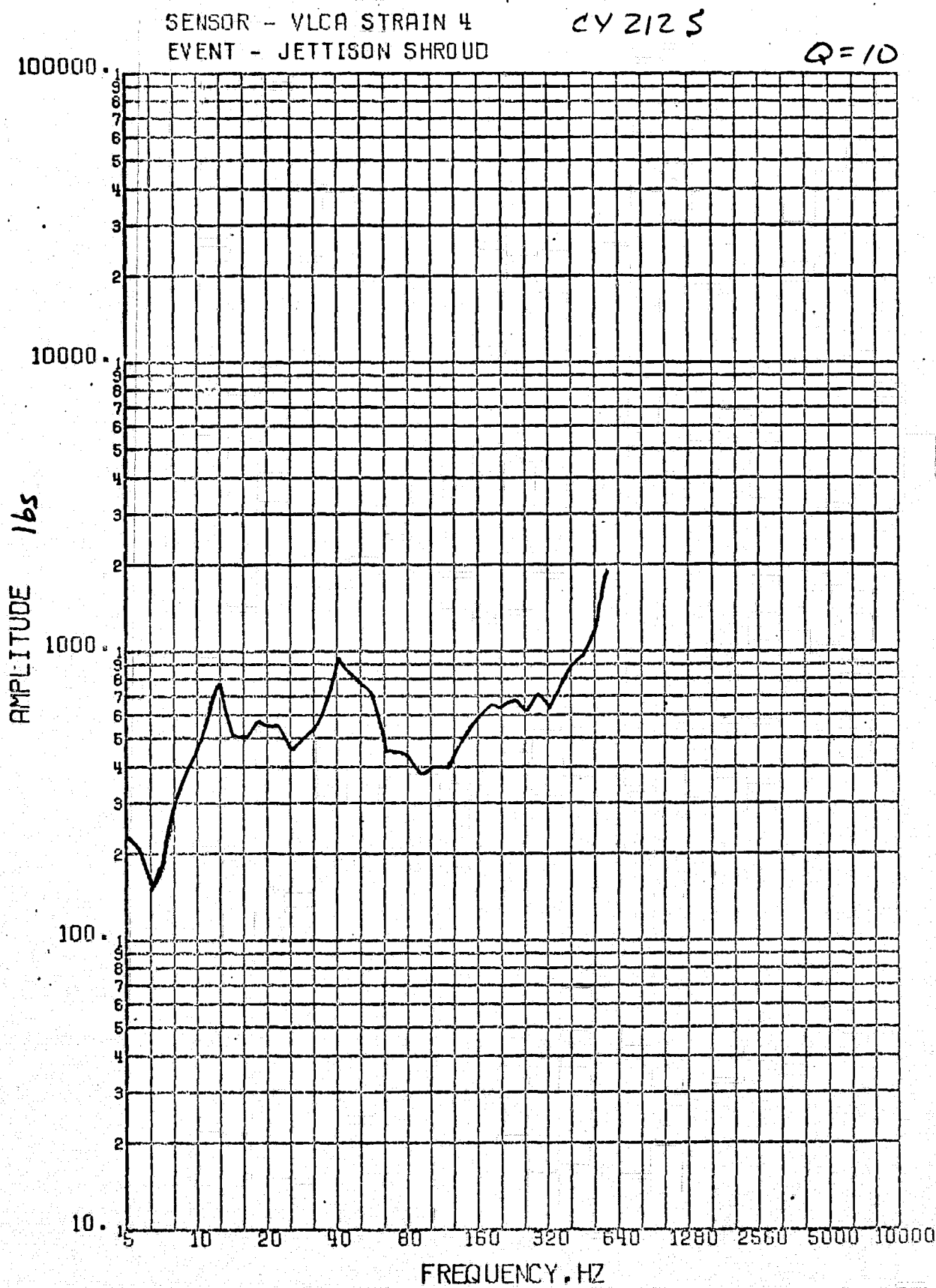
CY2115

Q=10



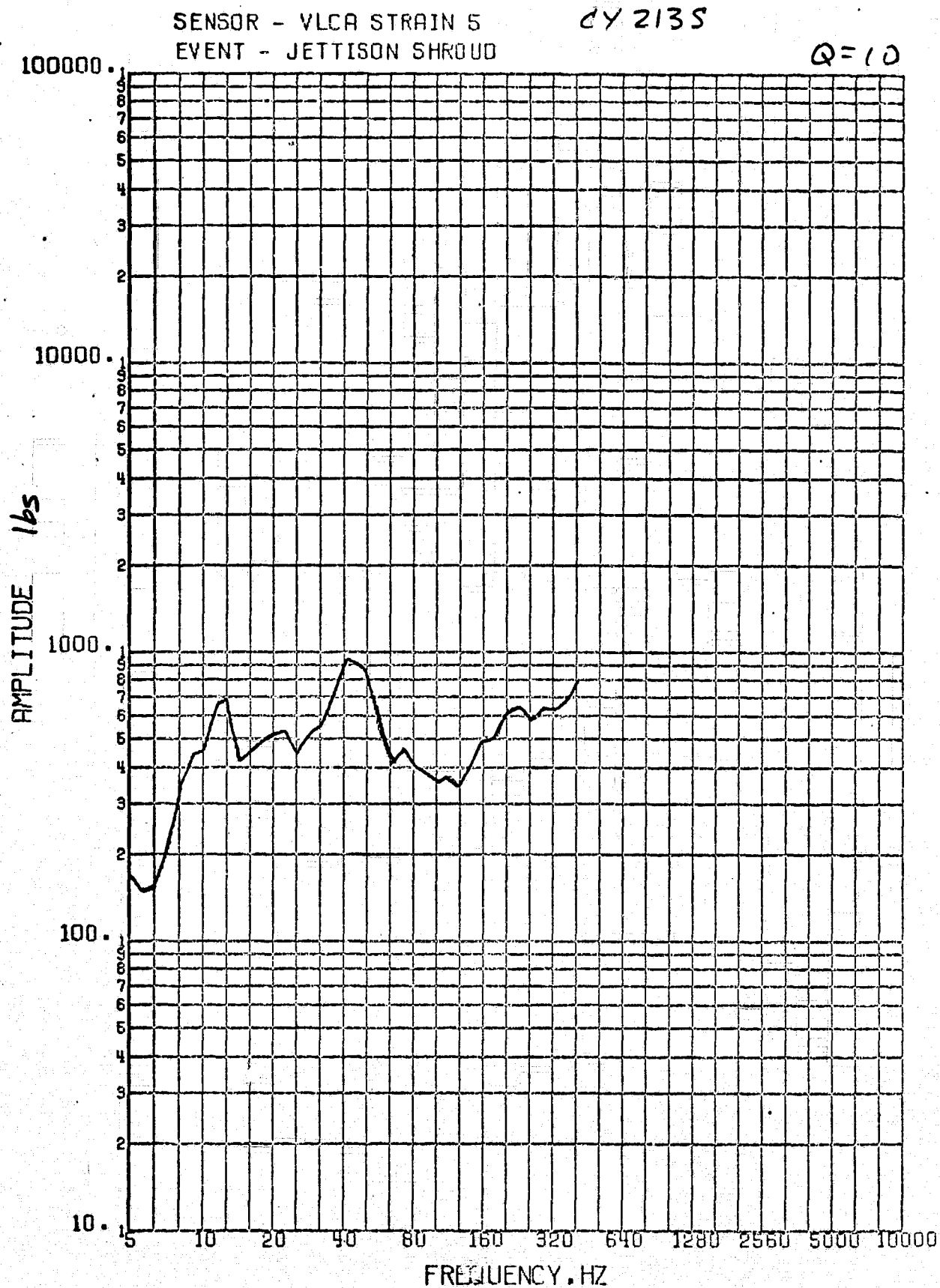
2.66

Figure 8 k



2.67

Figure 8 2



2.68

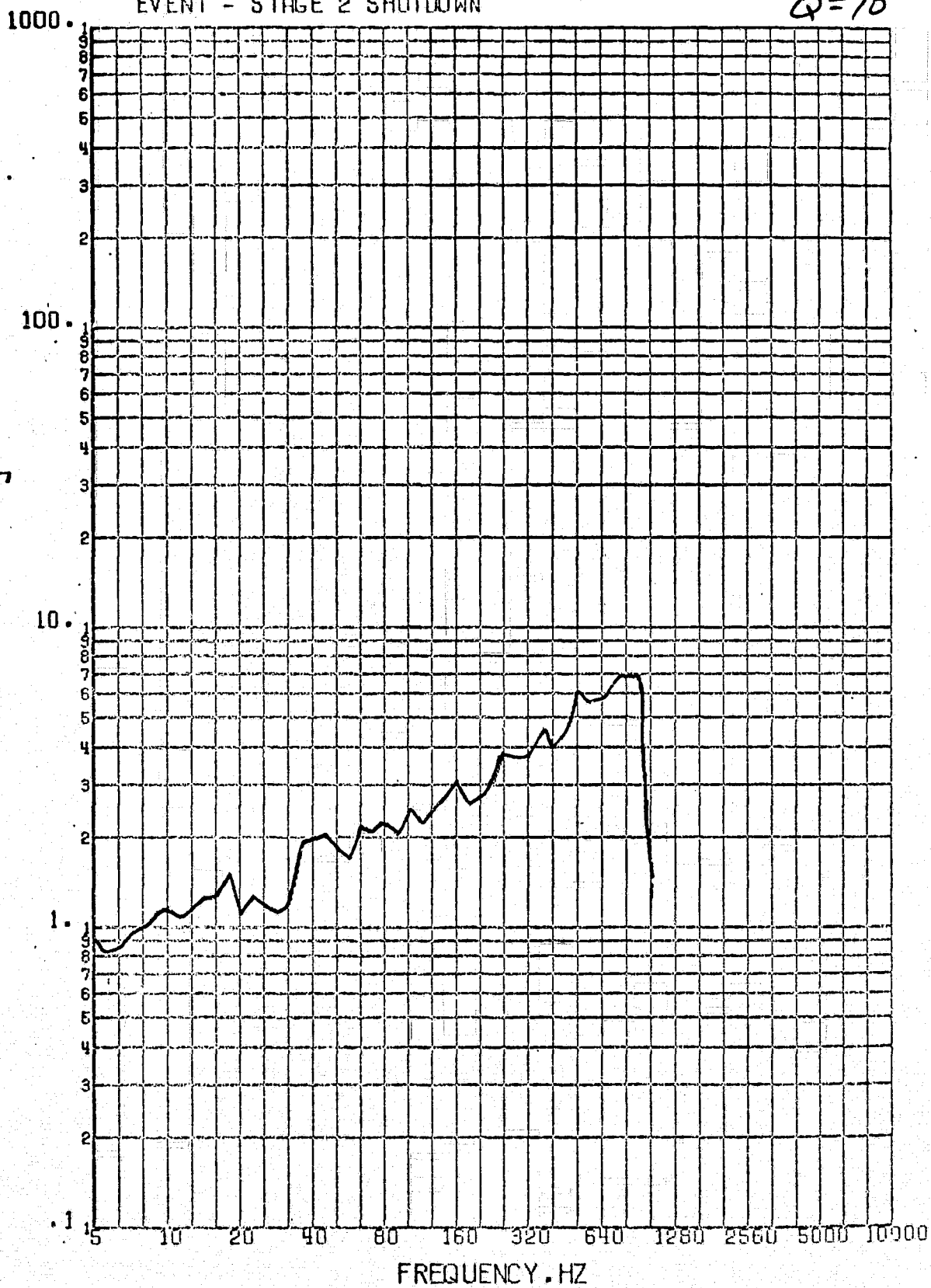
Figure 8 m

SENSOR - VDDS ACCEL 1
EVENT - STAGE 2 SHUTDOWN

CY201

Q=10

AMPLITUDE
g



2.69

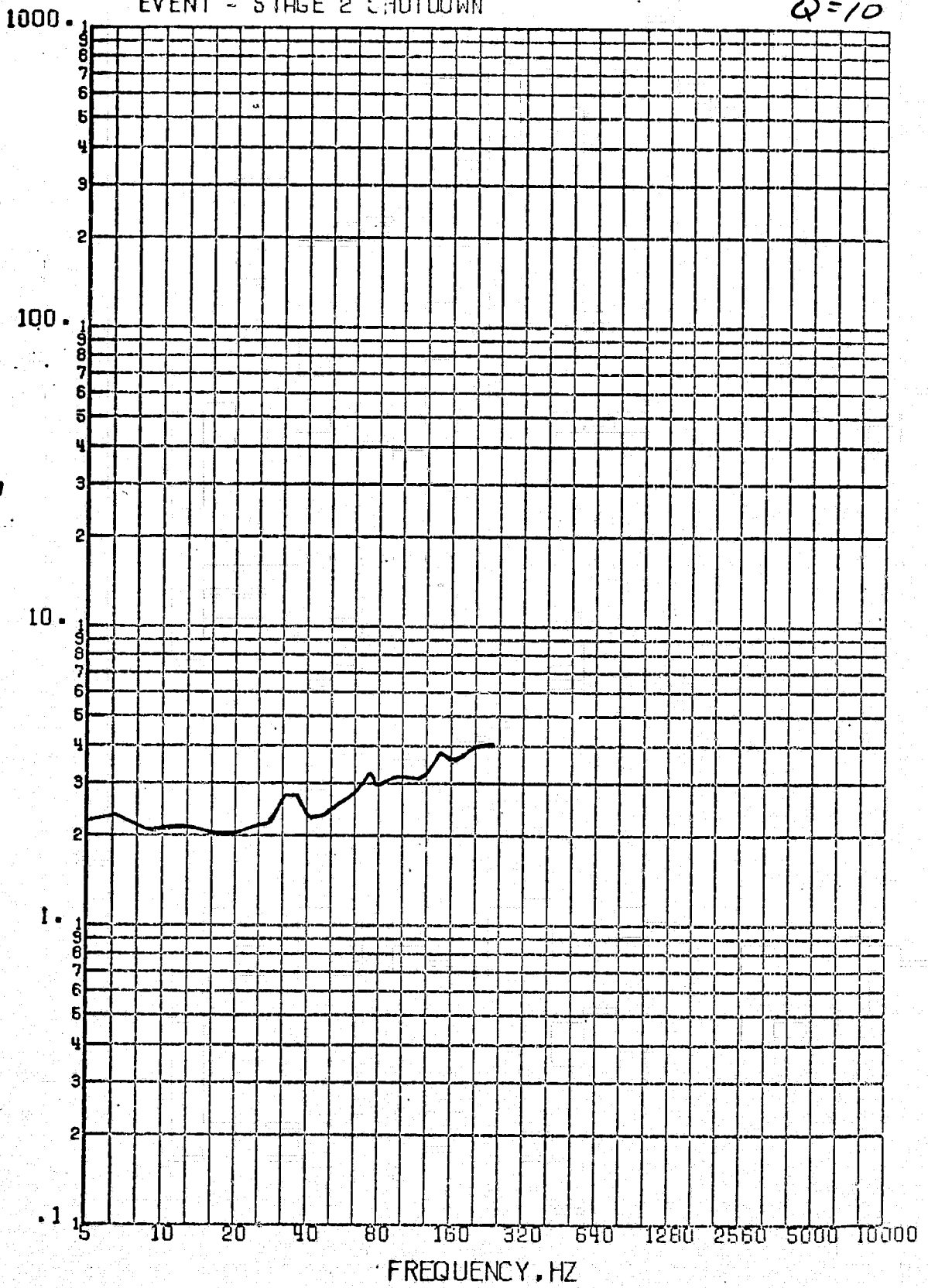
Figure 9 a

SENSOR - VOOS ACCEL 2
EVENT - STAGE 2 SHUTDOWN

CY202

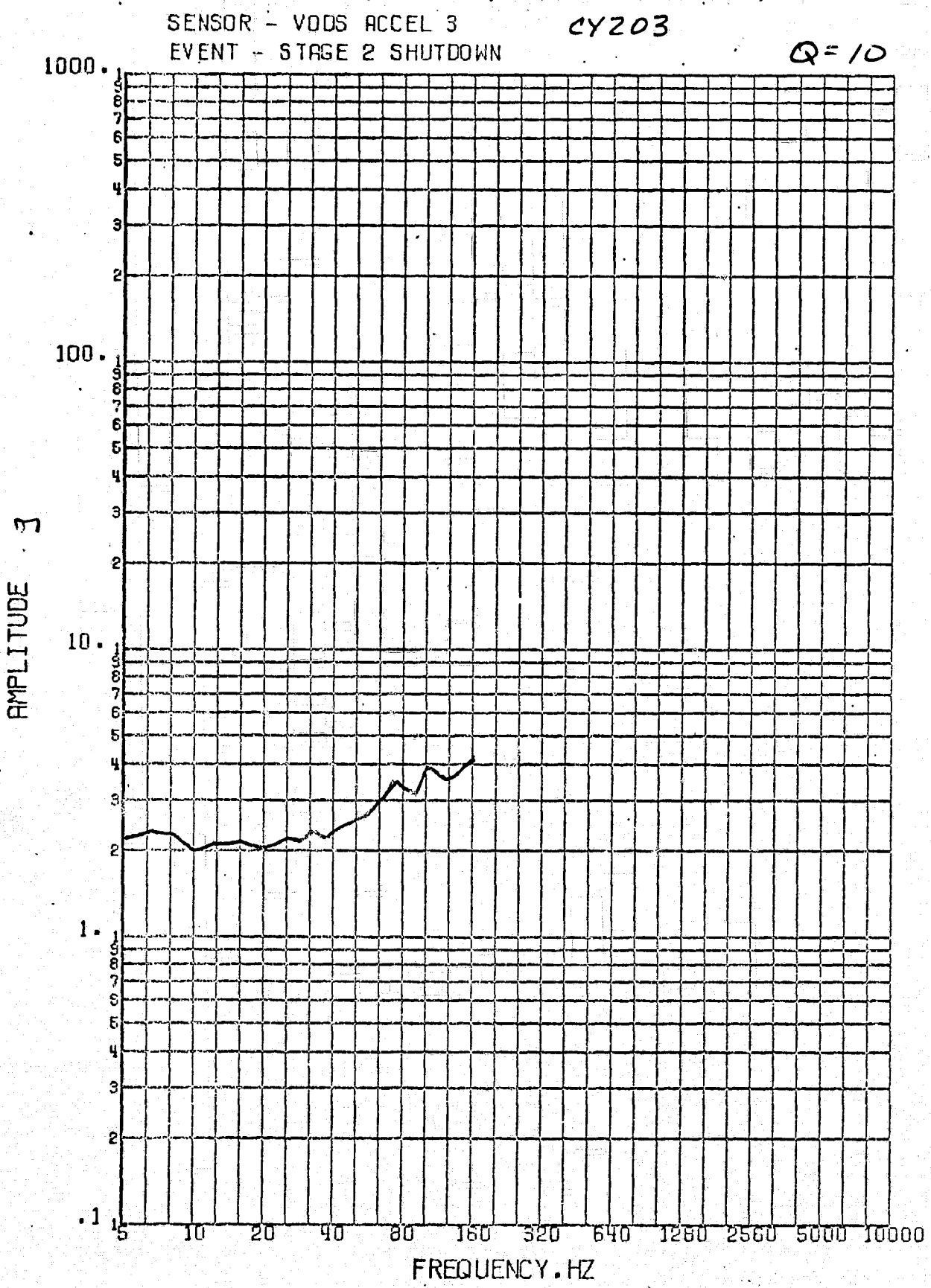
Q=10

AMPLITUDE 9



2.70

- Figure 96



2.71

Figure 9 c

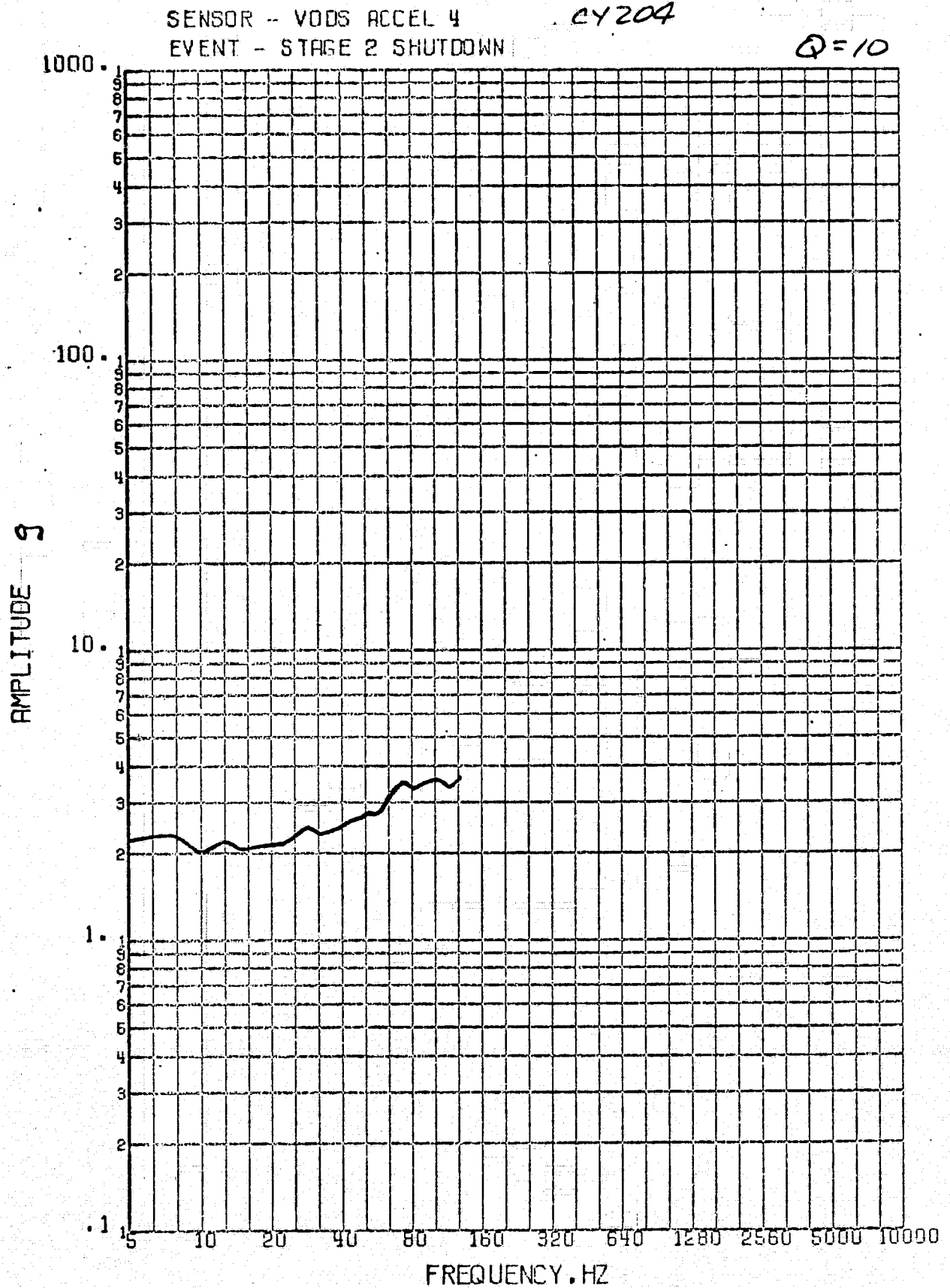
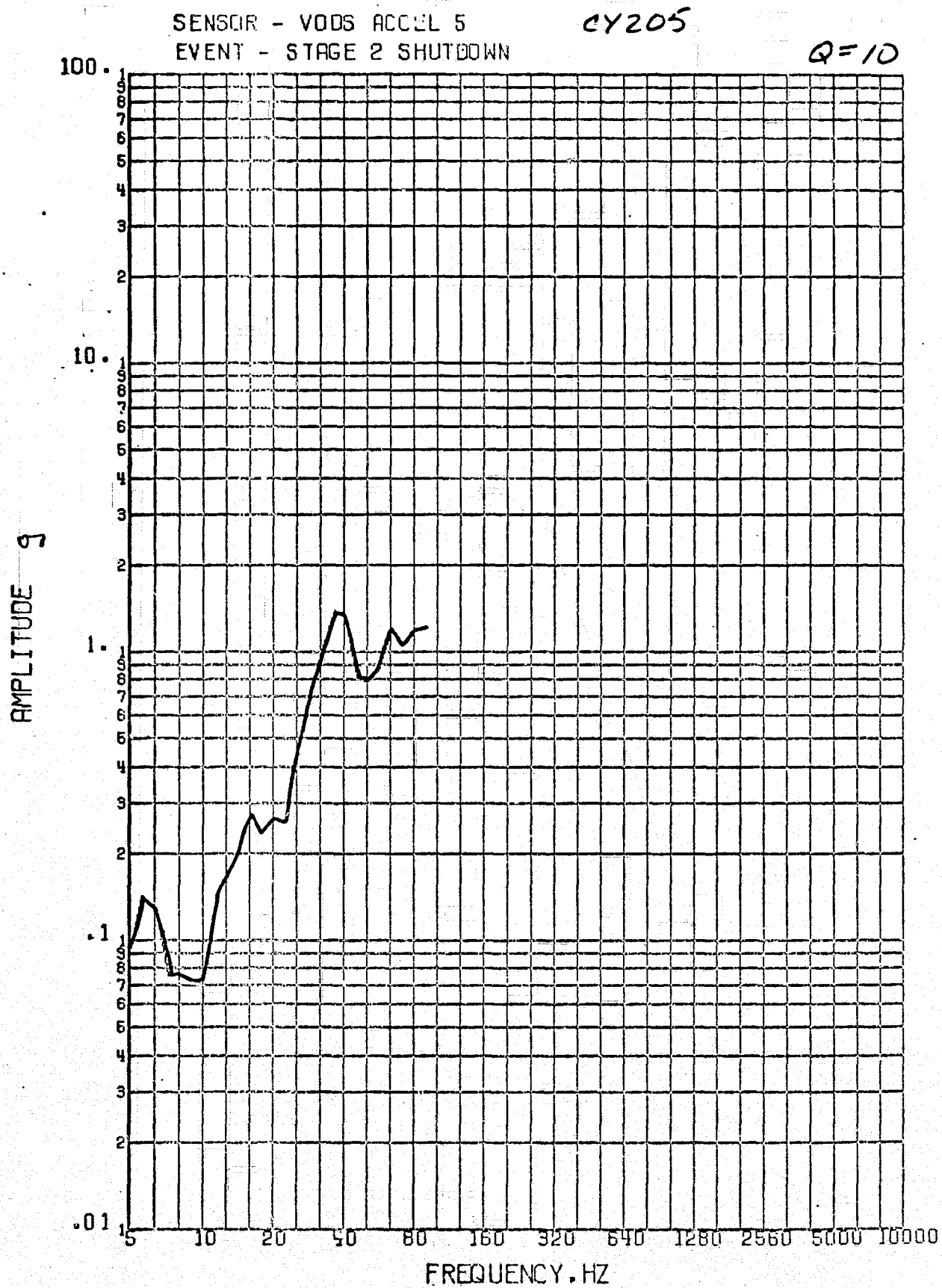


Figure 9 d



2.73

Figure 9e

SENSOR - V005 ACCEL 6
EVENT - STAGE 2 SHUTDOWN

CY206

Q=10

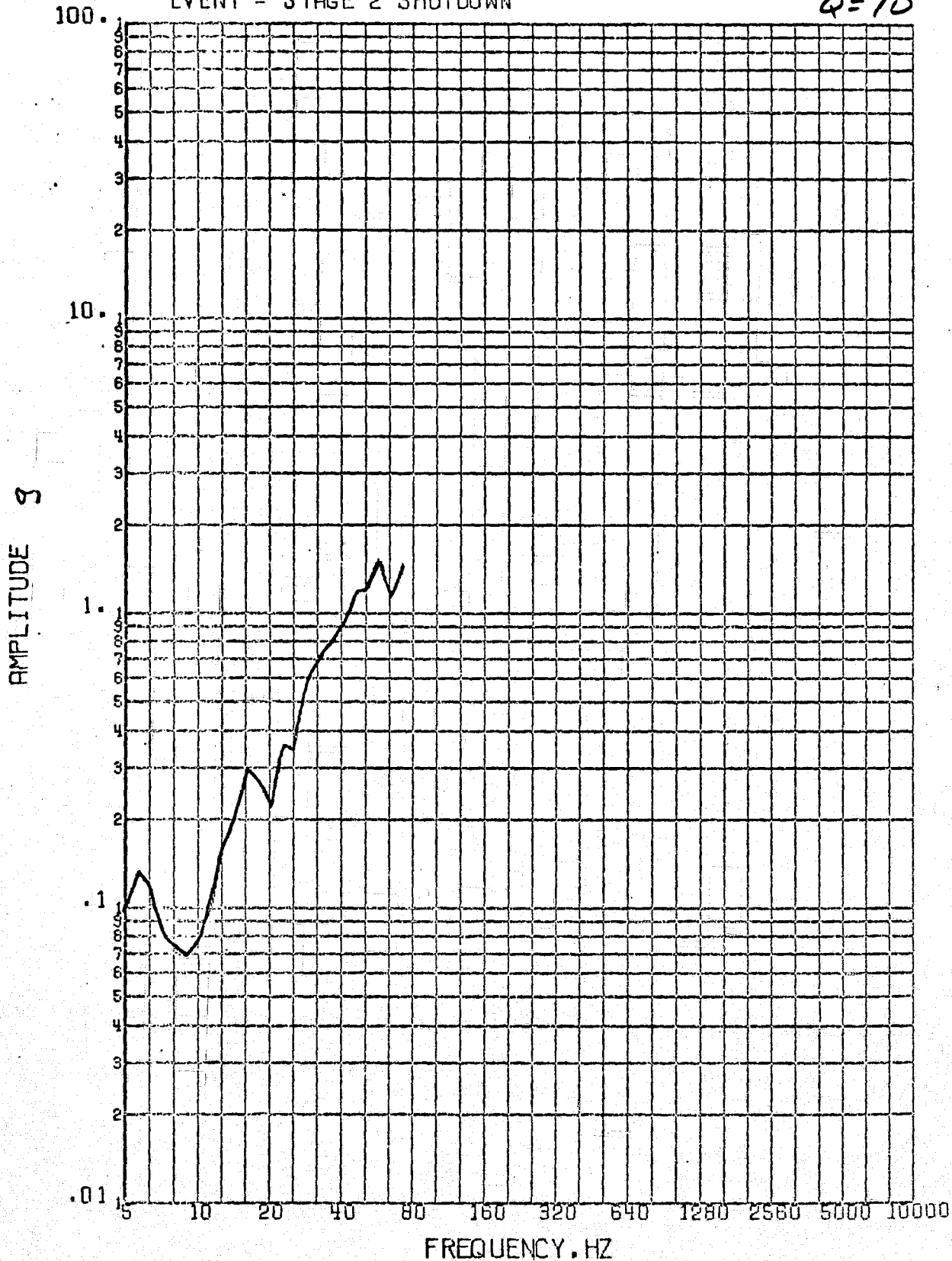


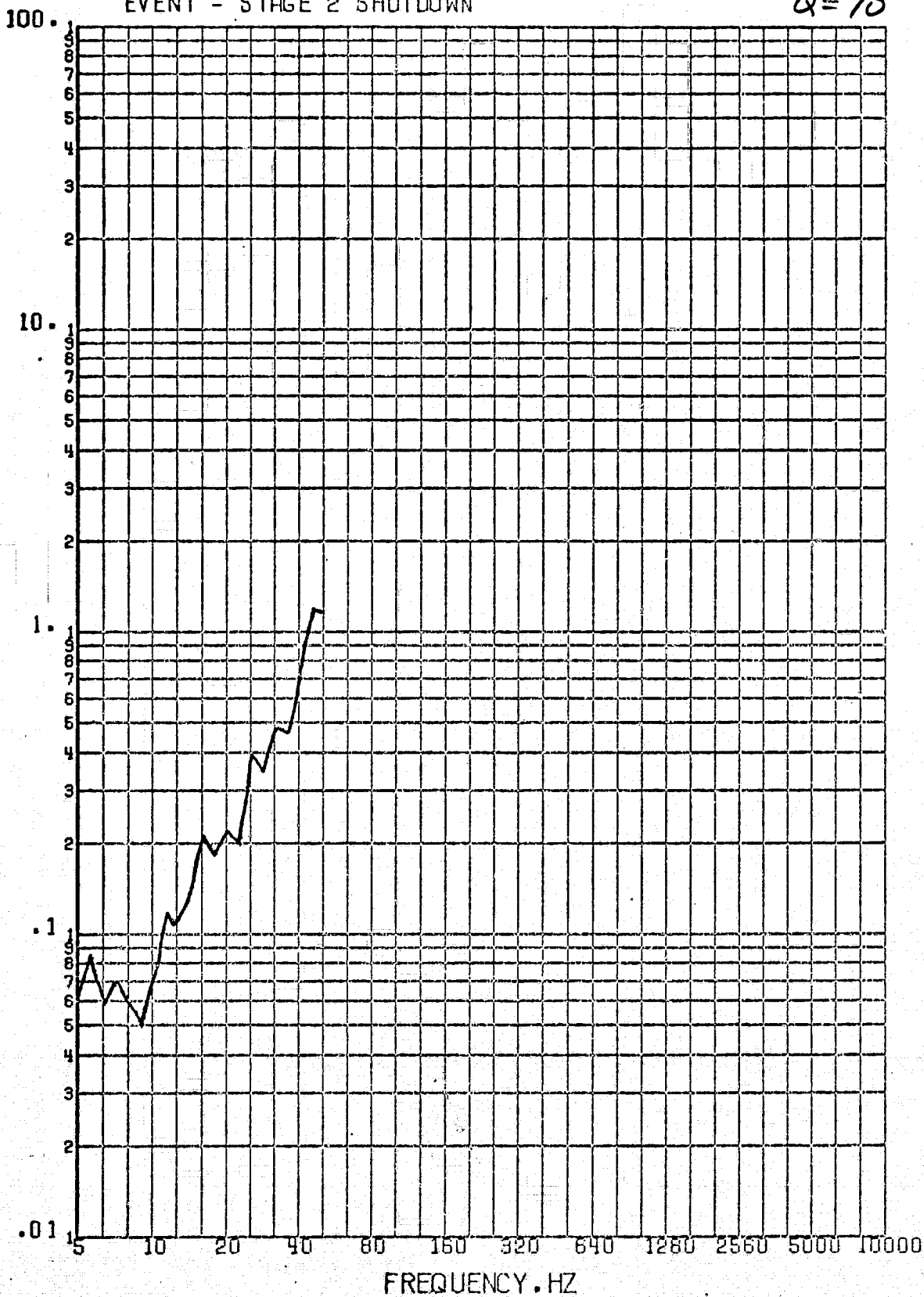
Figure 9f

SENSOR - VODS ACCEL 7
EVENT - STAGE 2 SHUTDOWN

CY 207

Q=10

AMPLITUDE g



2.75

- Figure 9 g

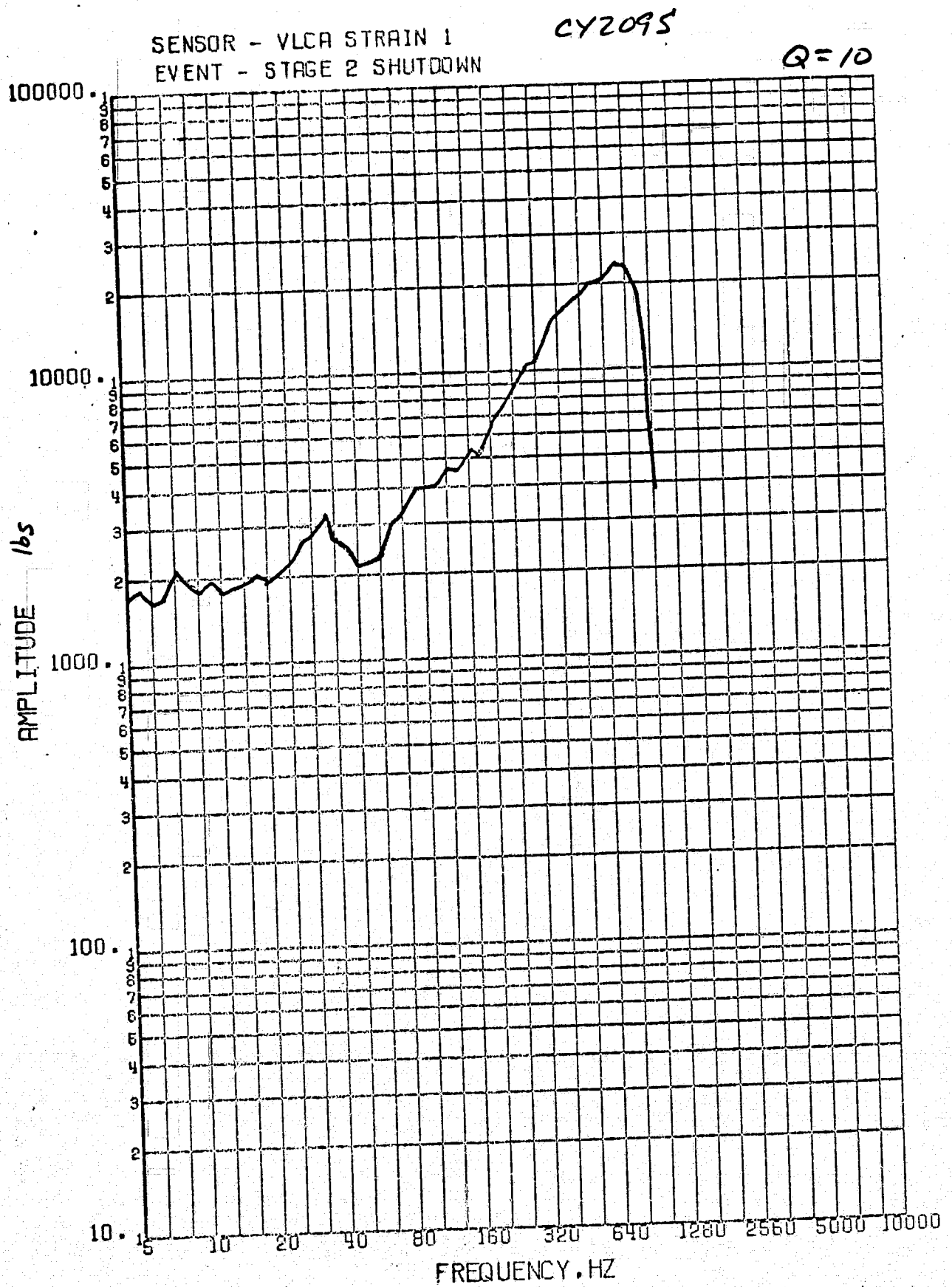
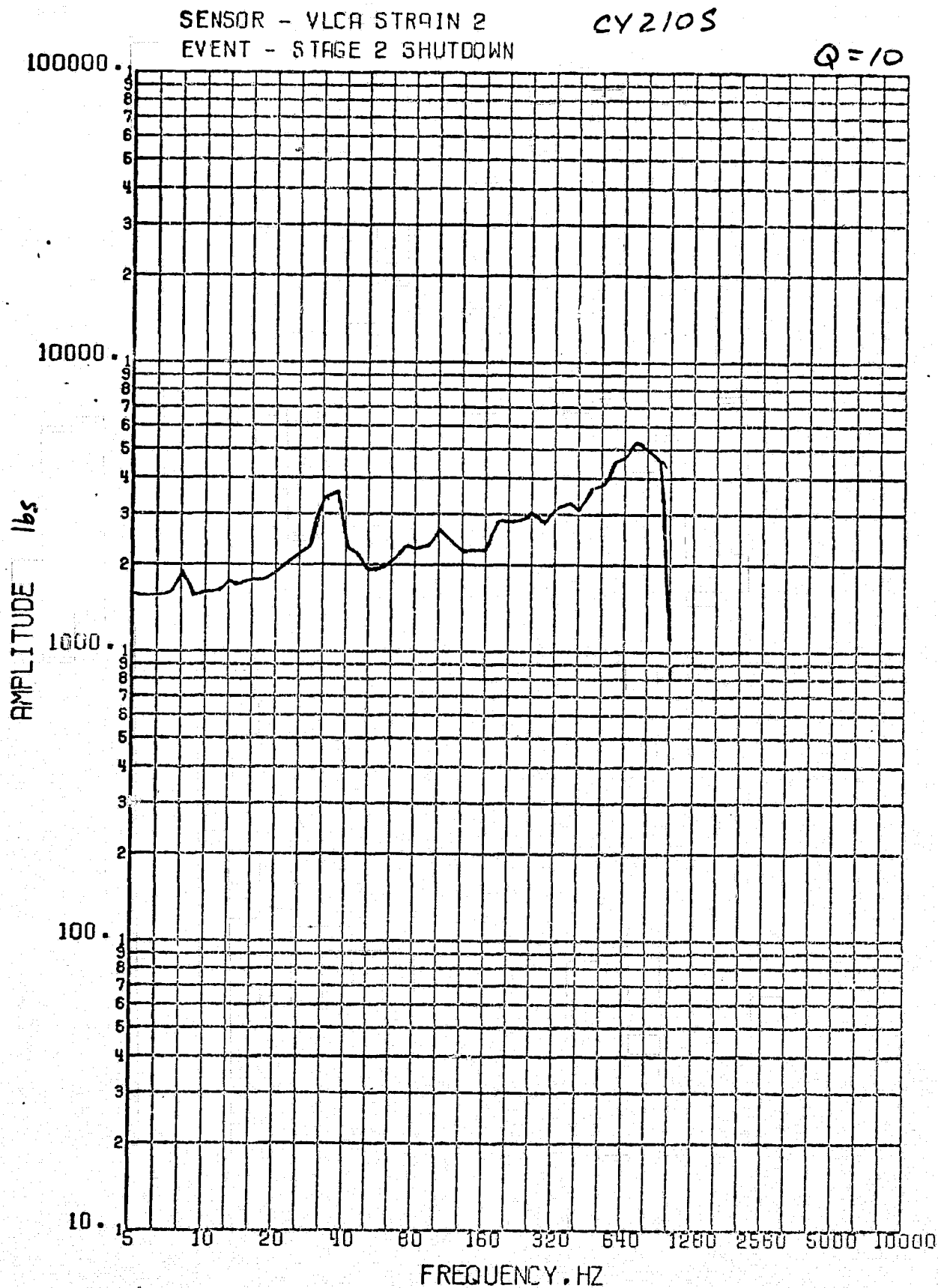


Figure 9 R



- Figure 9 j

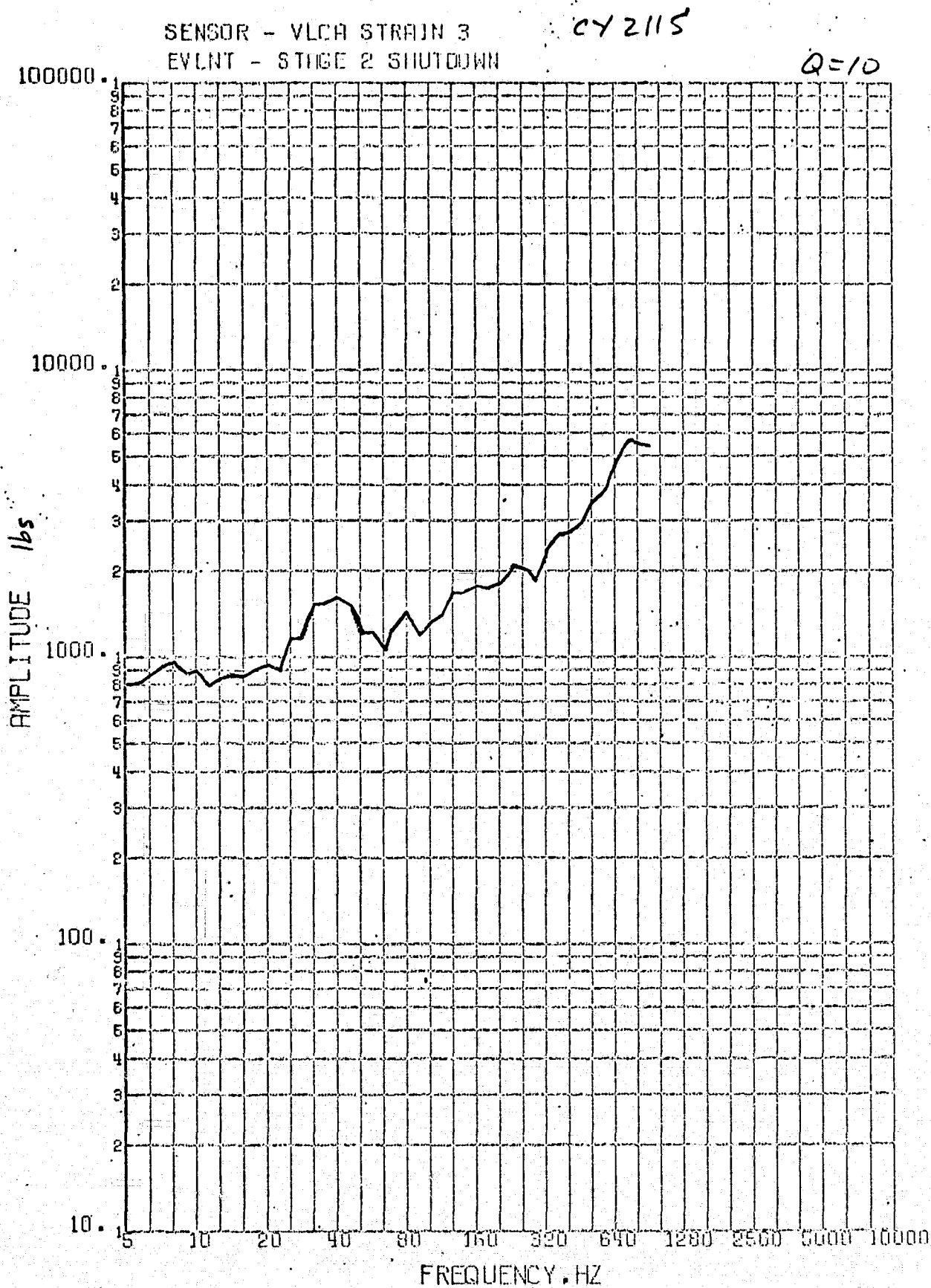


Figure 9 k

SENSOR - VLCH STRAIN 4
EVENT - STAGE 2 SHUTDOWN

CY2125

Q=10

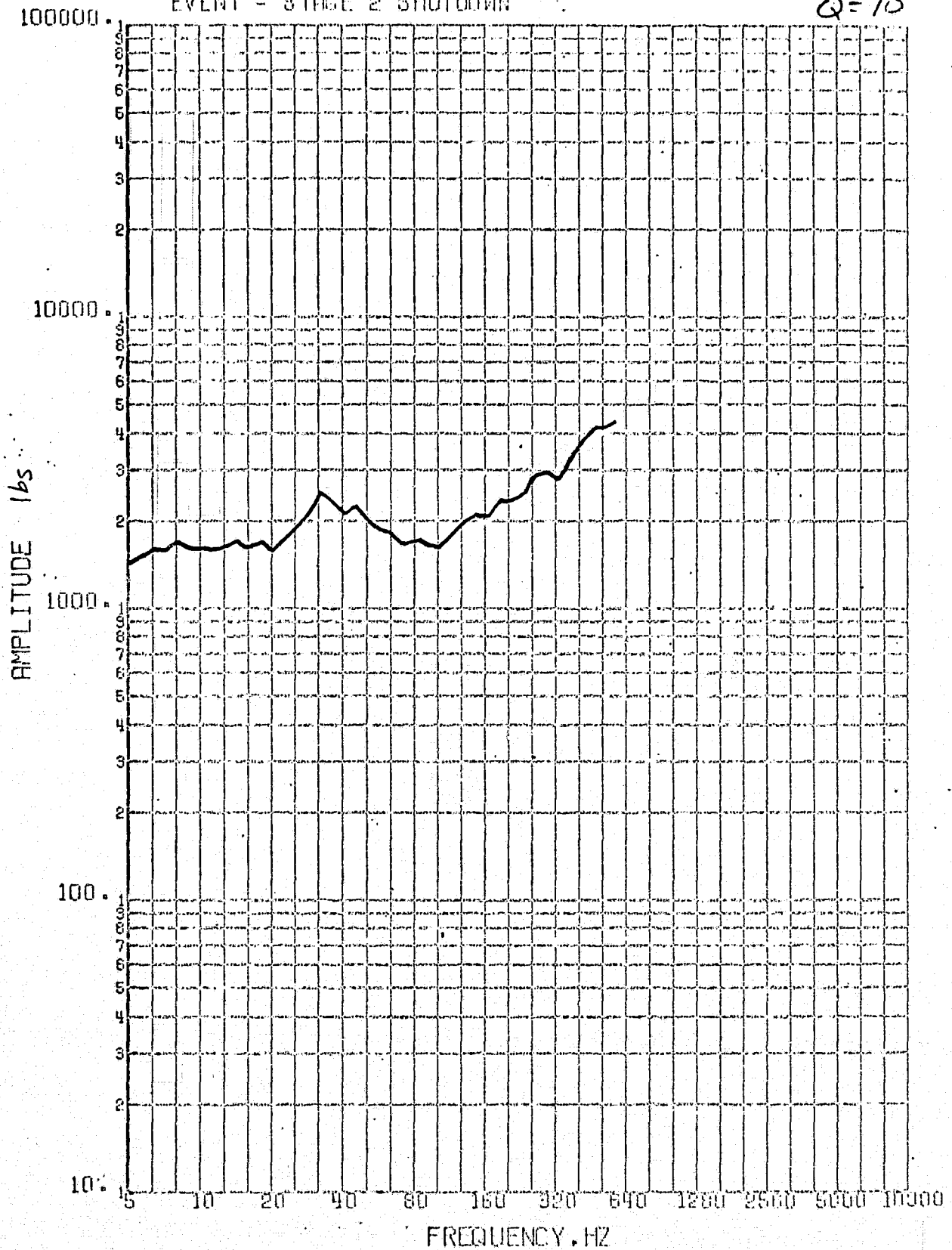
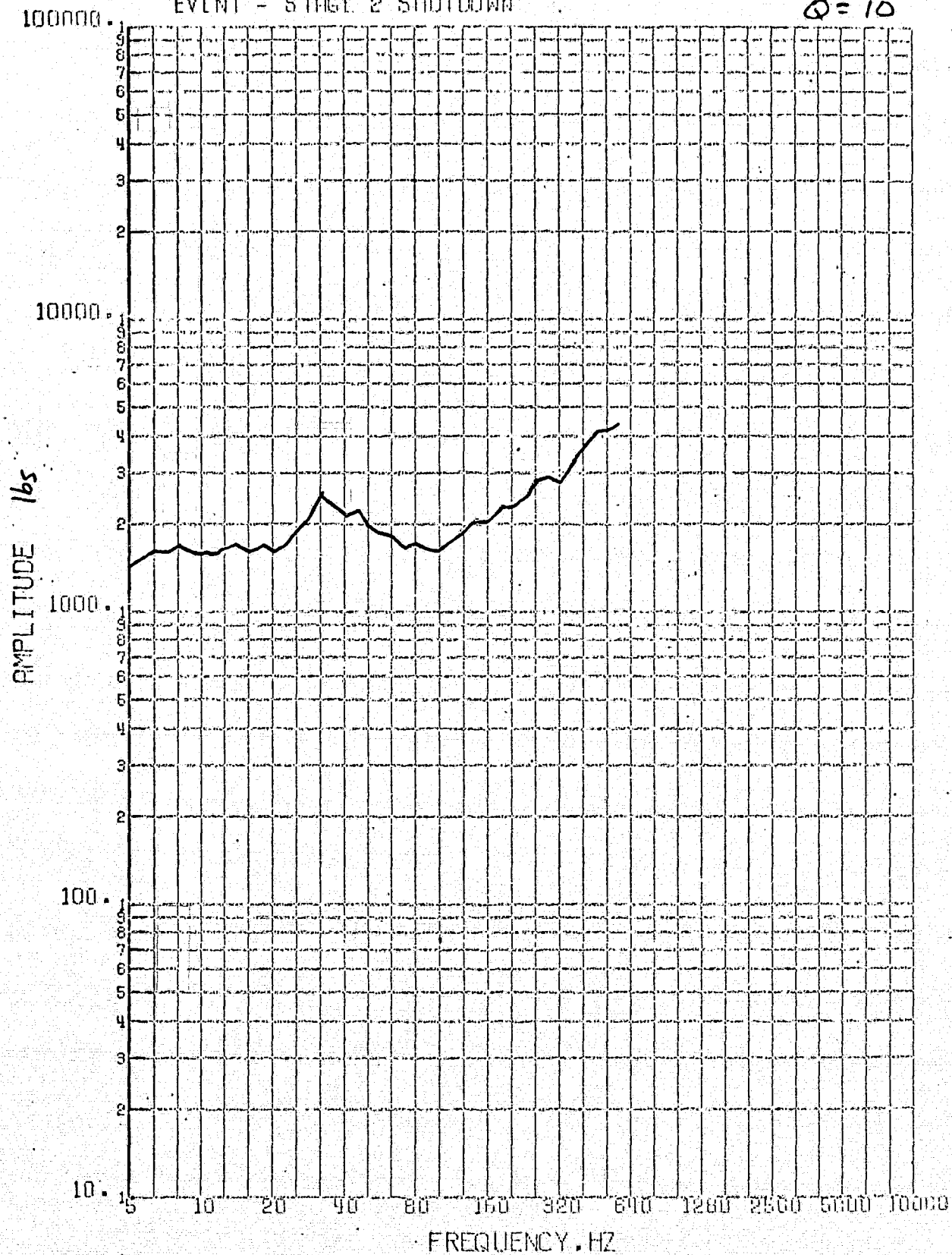


Figure 9 e

SENSOR - VLCA STRAIN 5
EVENT - STAGE 2 SHUTDOWN

CY213S

Q = 10

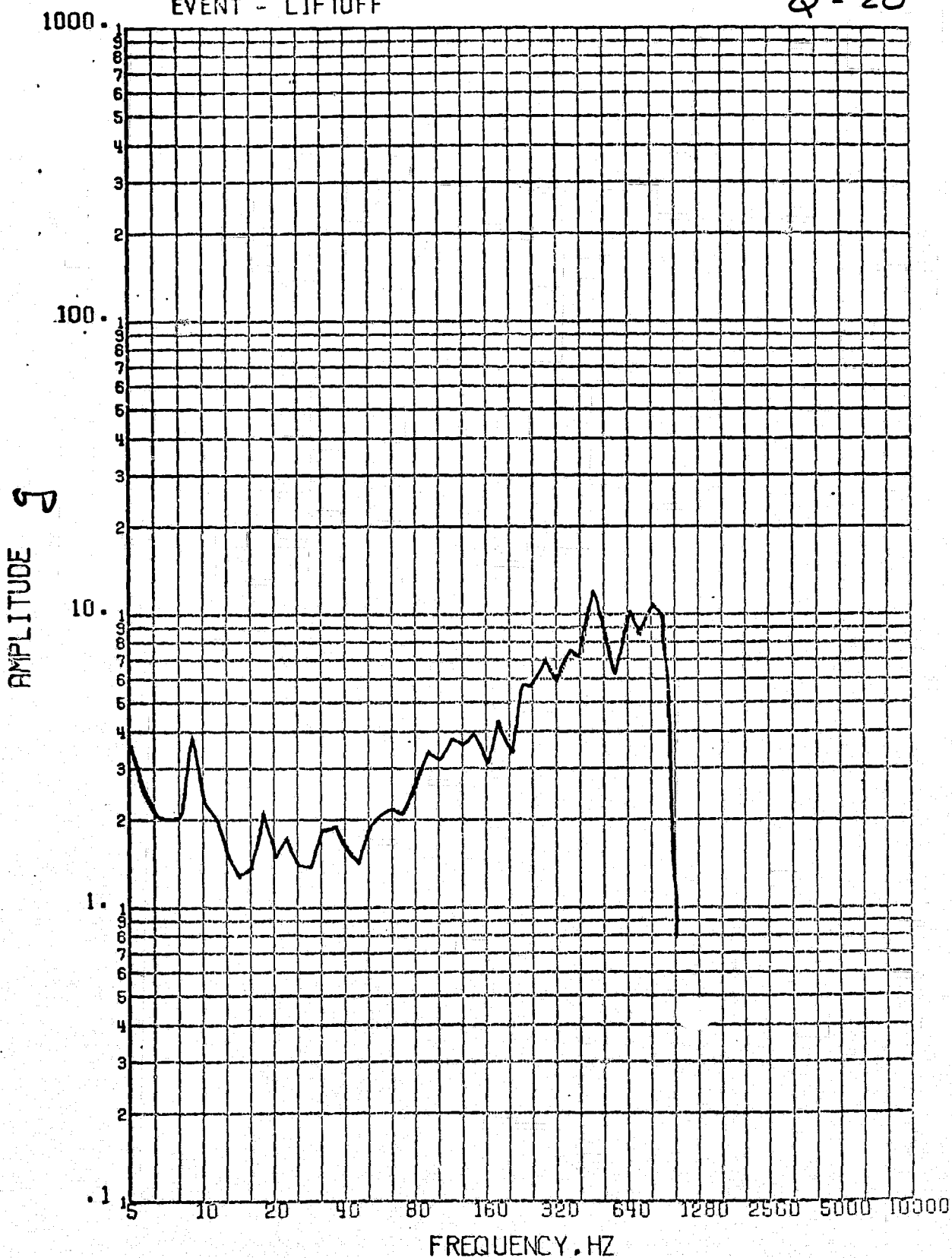


2.80

Figure 9 m

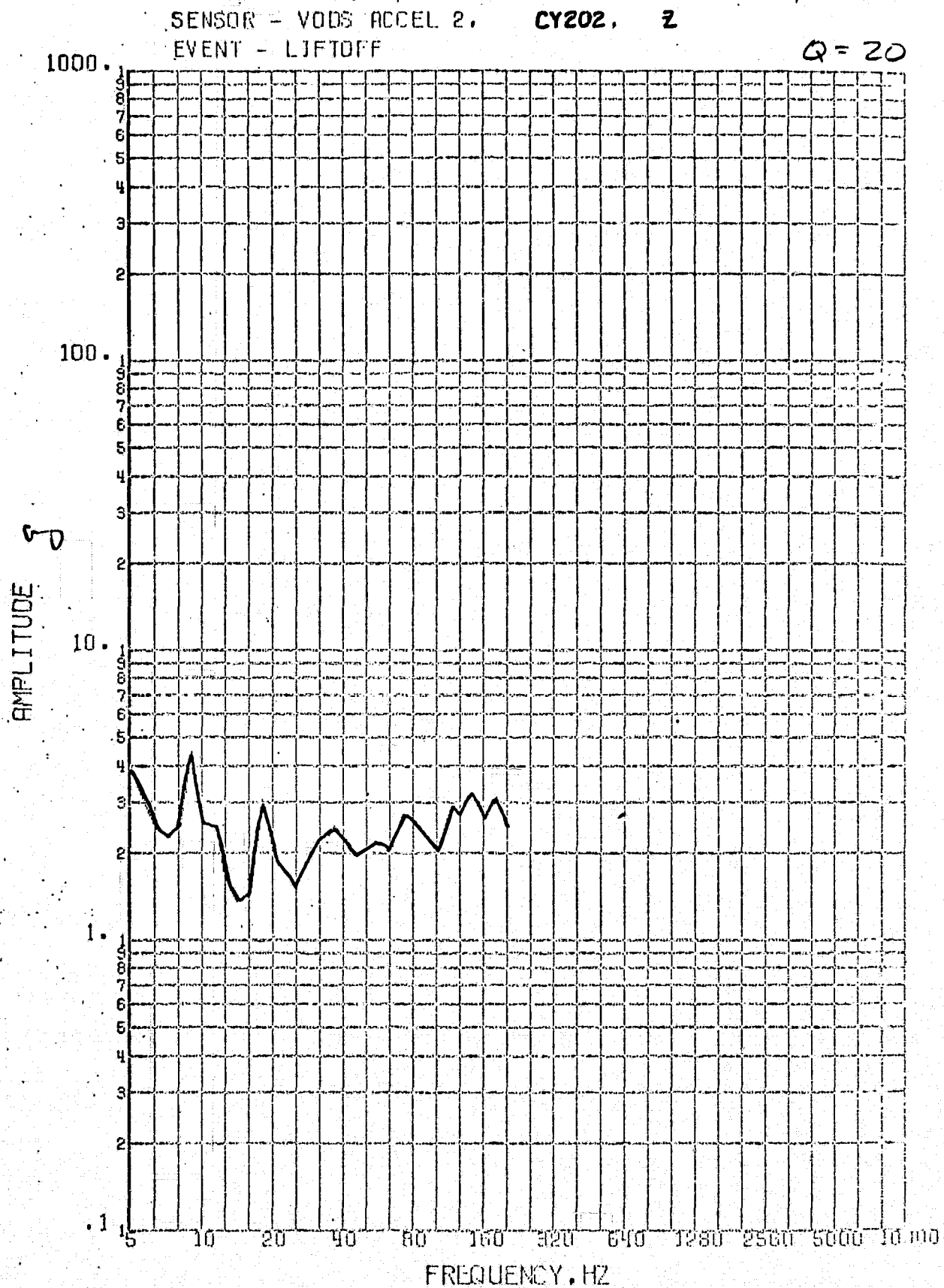
SENSOR - VIDS ACCEL 1, CY201, Z
EVENT - LIFTOFF

Q = 20



2.81

Figure 10 a



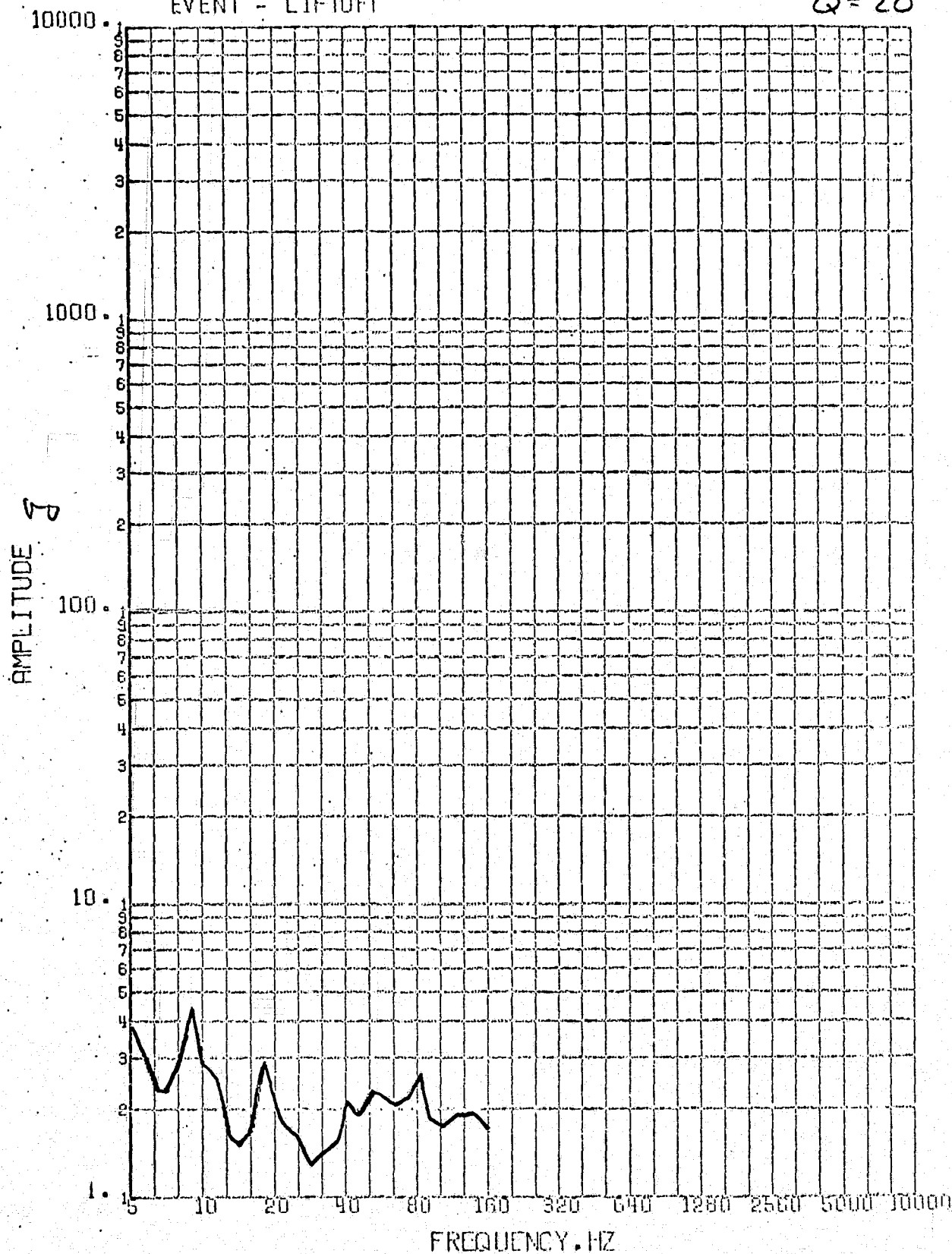
2.82

Figure 10 b

SENSOR - V006 ACCEL 3.
EVENT - LIFTOFF

CY203. 2

Q=20



2.83

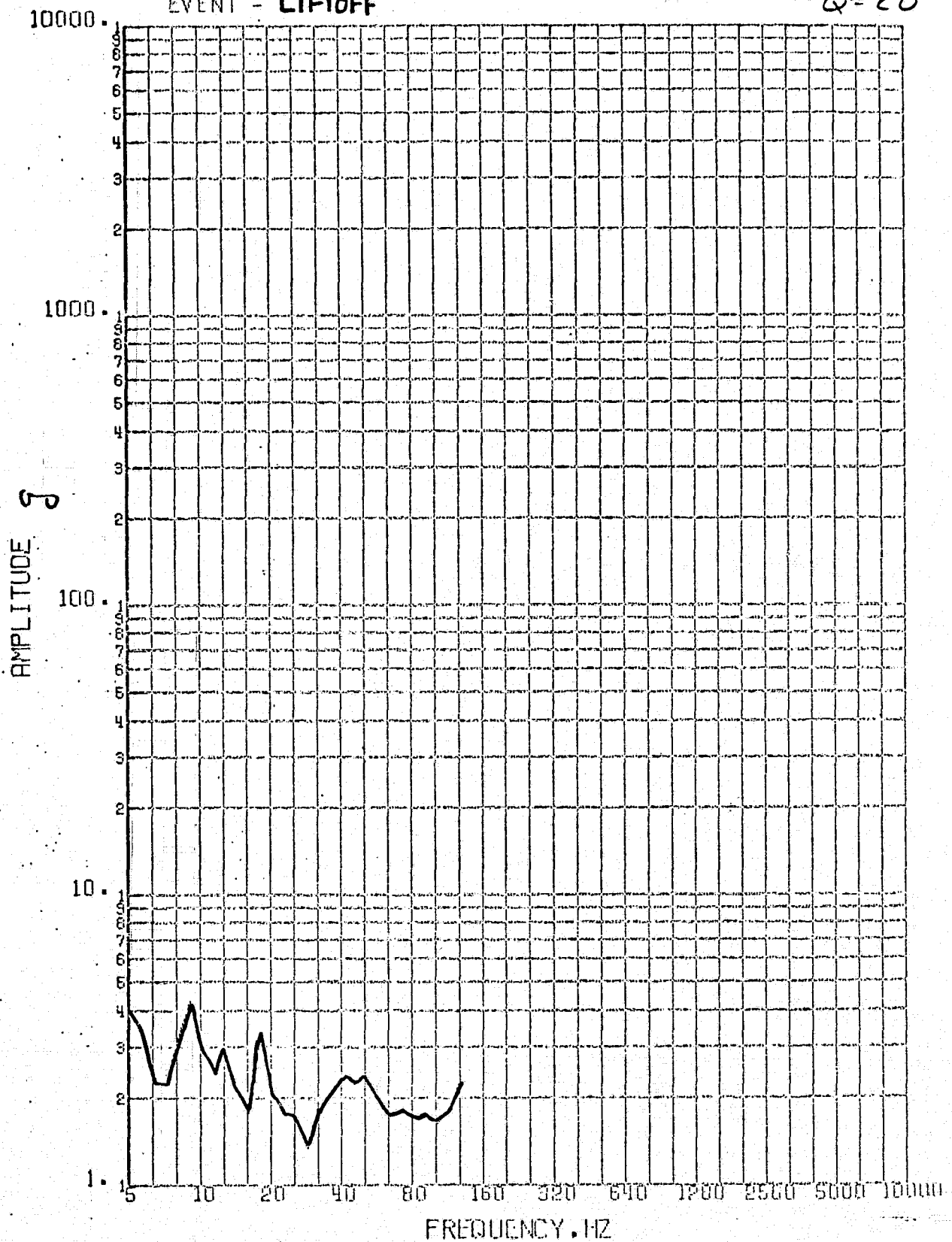
Figure 10c

SENSOR - V005 ACCEL 4,
EVENT - LIFTOFF

CY204.

2/

Q=20



2.84

Figure 10 d

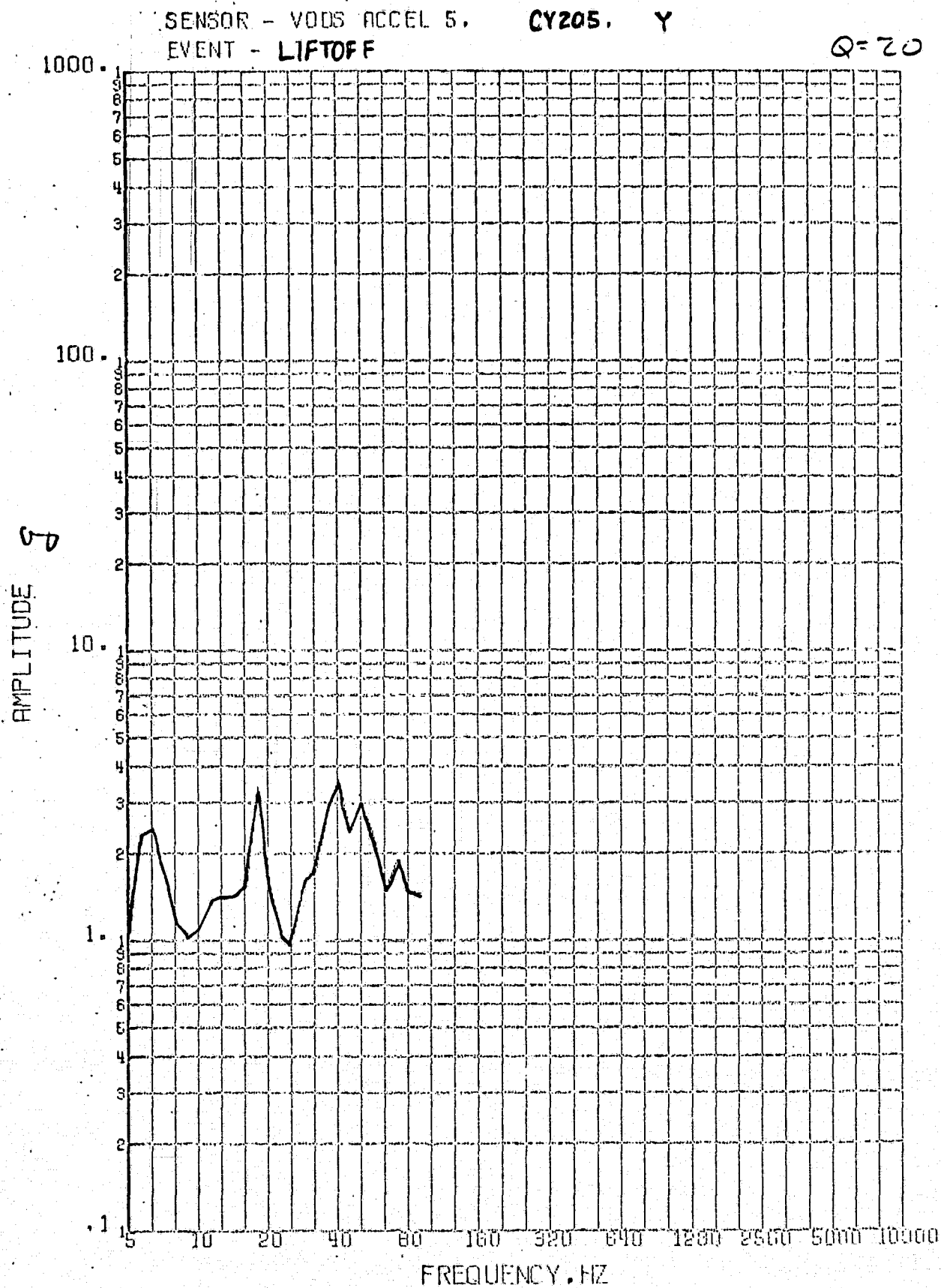


Figure 10 e

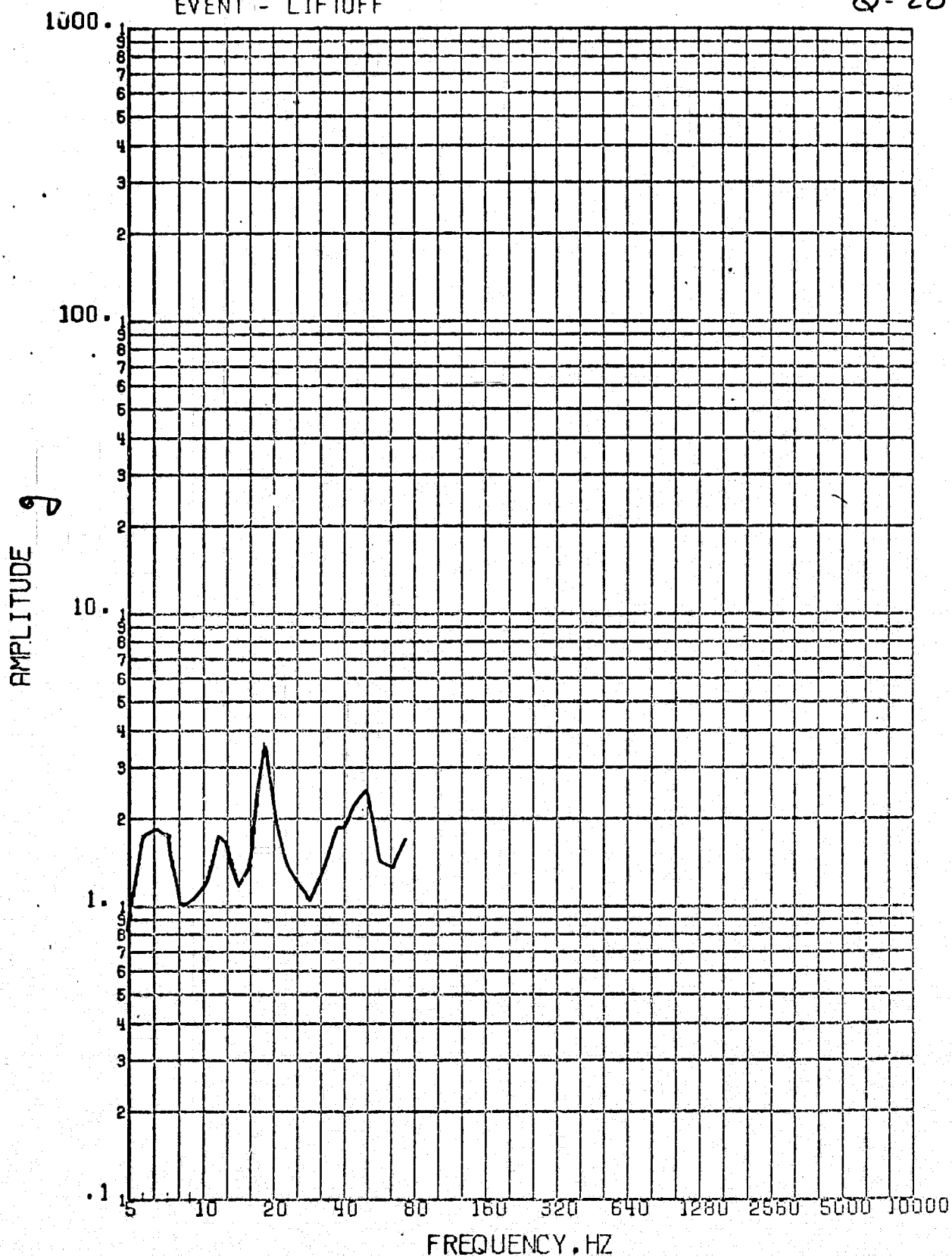
SENSOR - VODS ACCEL 6.

CY206.

Y

EVENT - LIFTOFF

Q=20



2.86

- Figure 10 f

SENSOR - VODS ACCEL 7. CY207. X
EVENT - LIFTOFF

Q=20

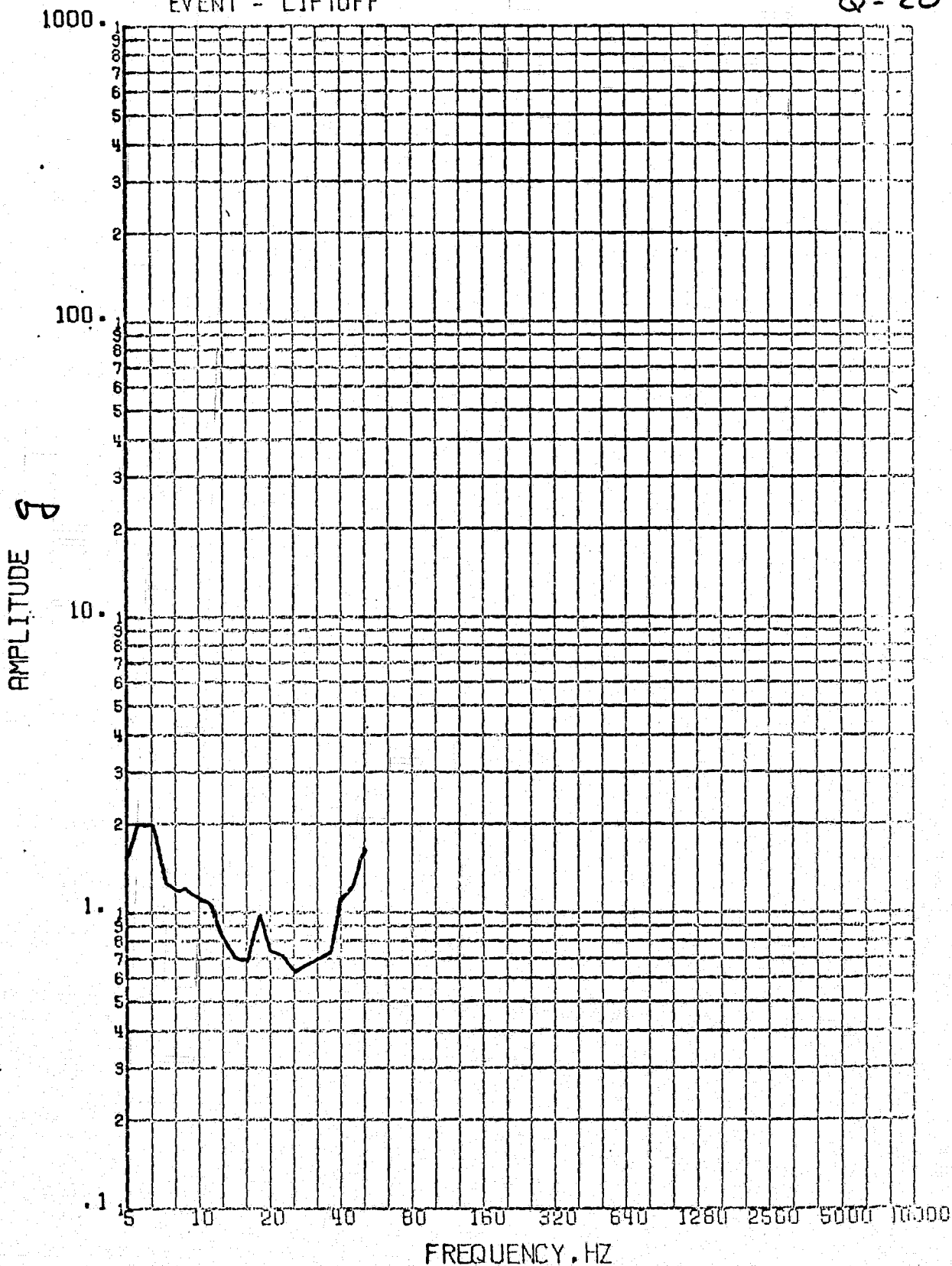


Figure 10 g

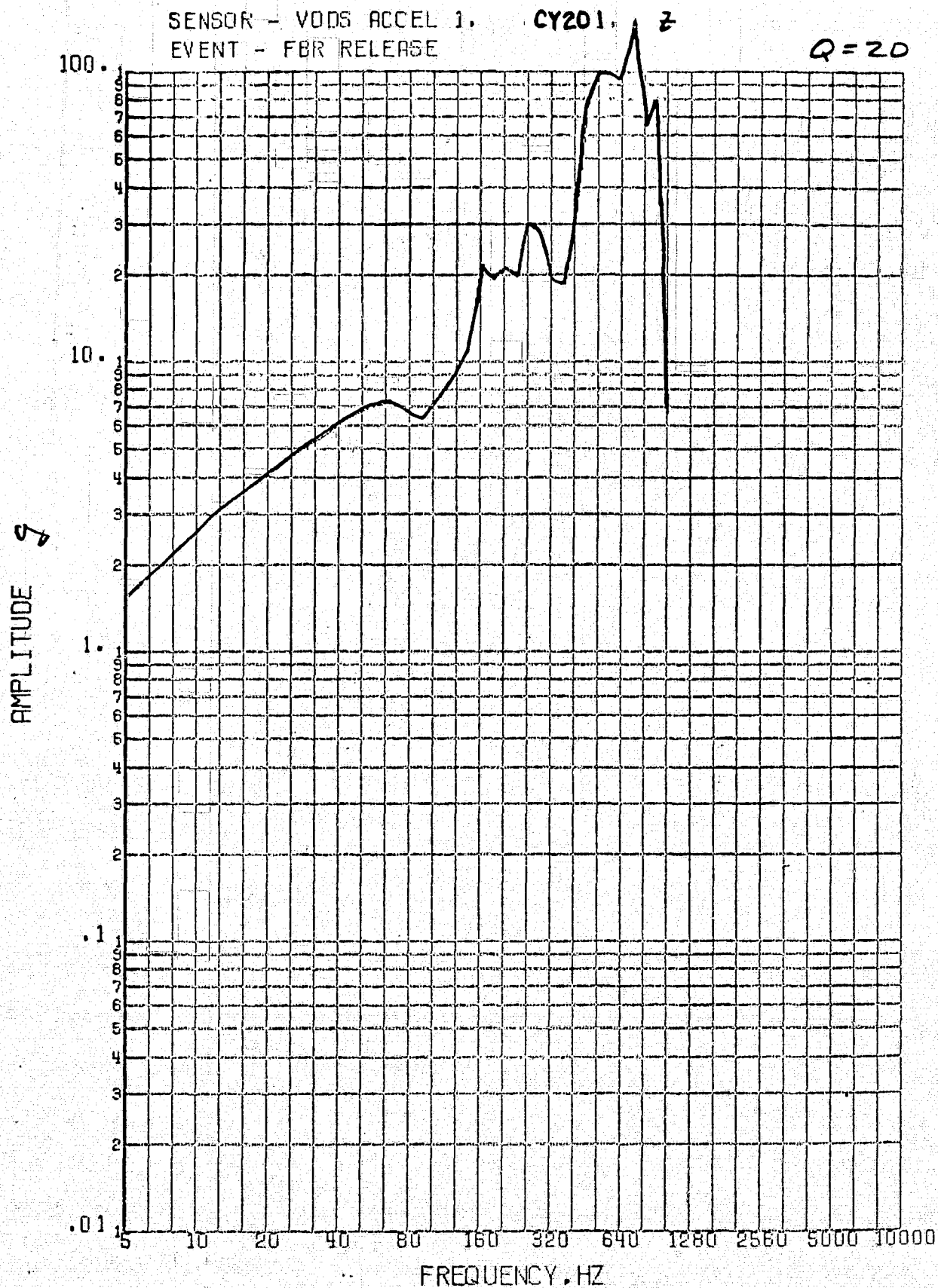


Figure 11 a

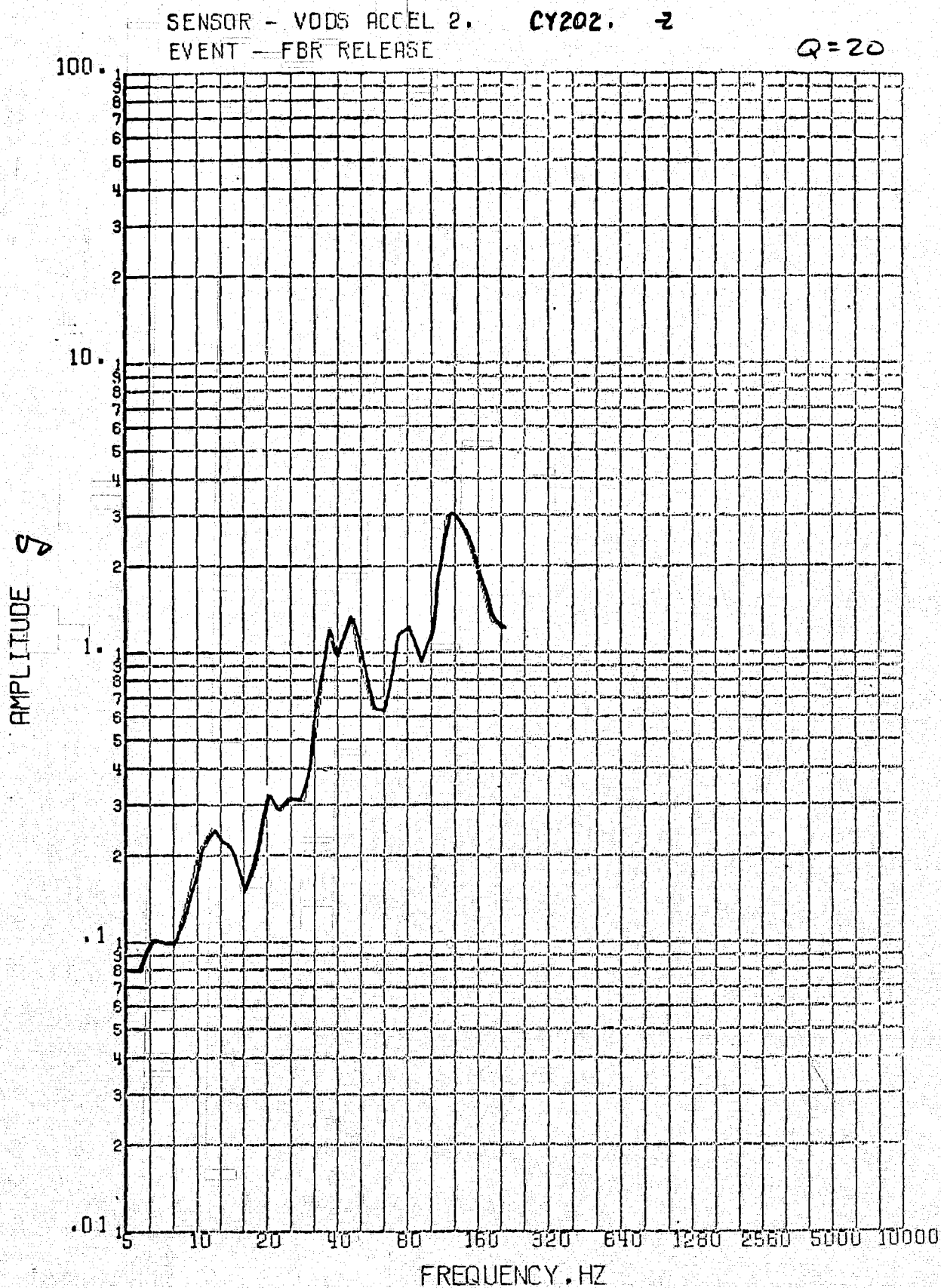


Figure 11 b

Revision A
4-9-74

SENSOR - VDDS ACCEL 3, CY203, 2
EVENT - FBR RELEASE

Q=20

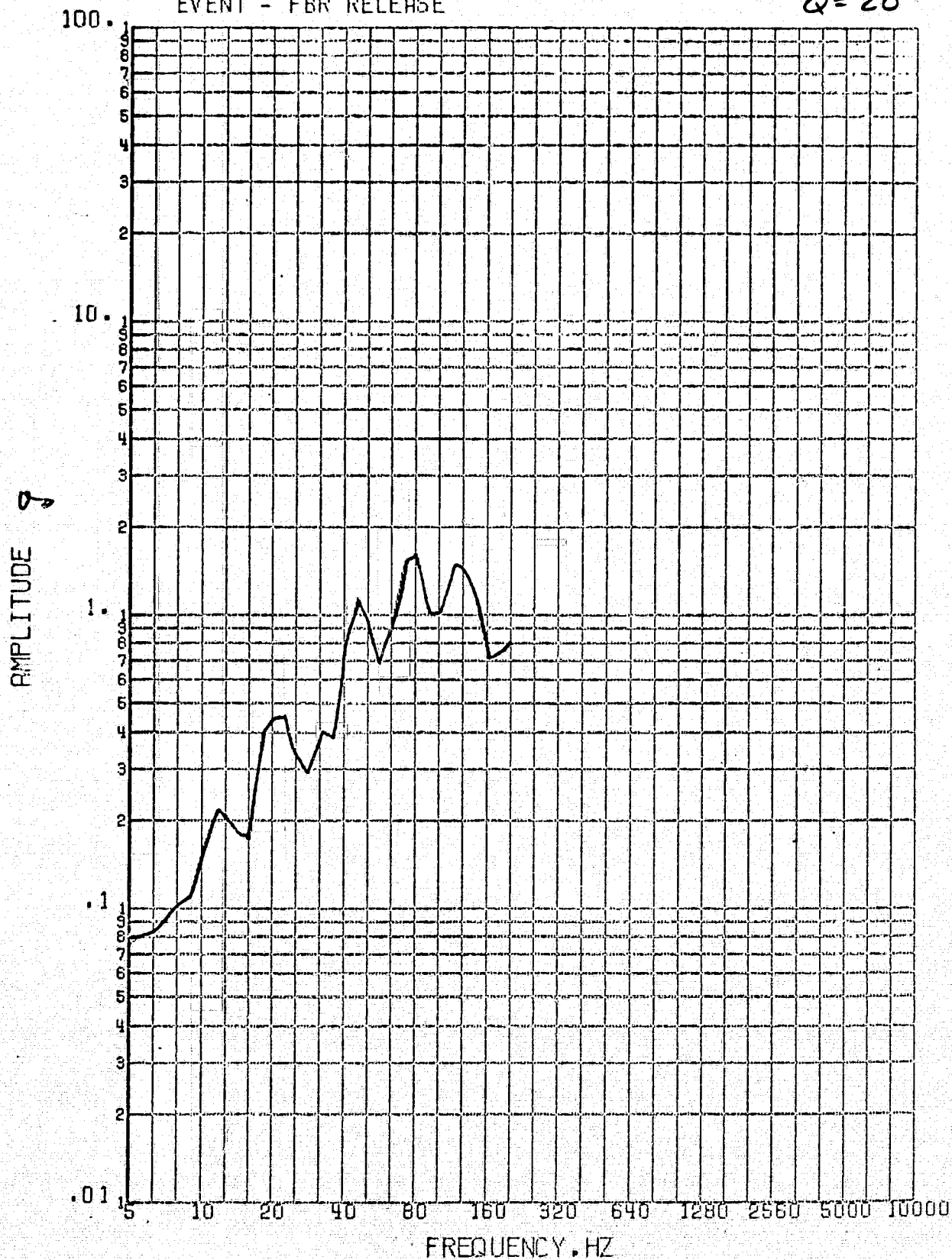


Figure 11c

Revision A
4-9-74

SENSOR - VDD5 ACCEL 4, CY204, 2
EVENT - FBR RELEASE

Q=20

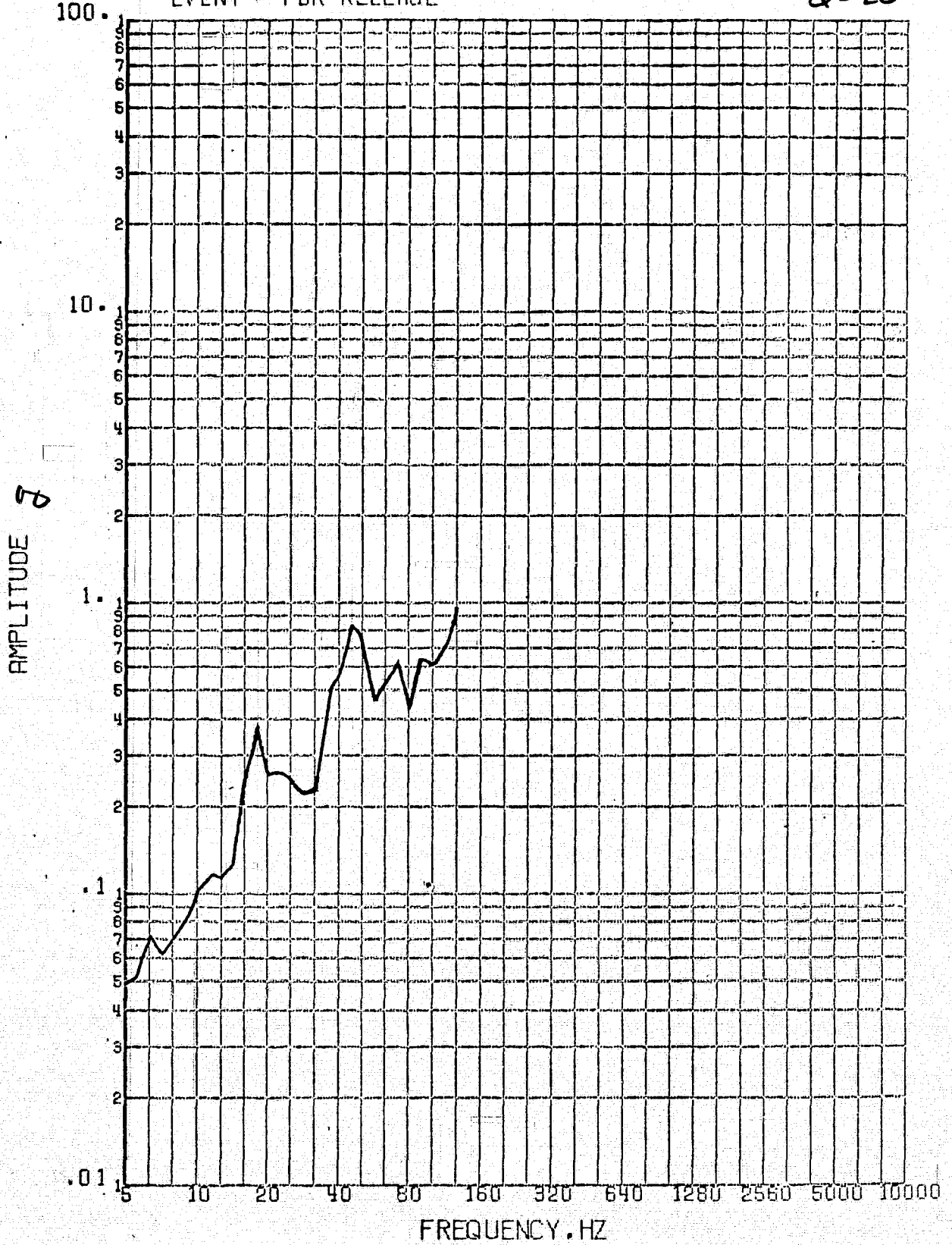


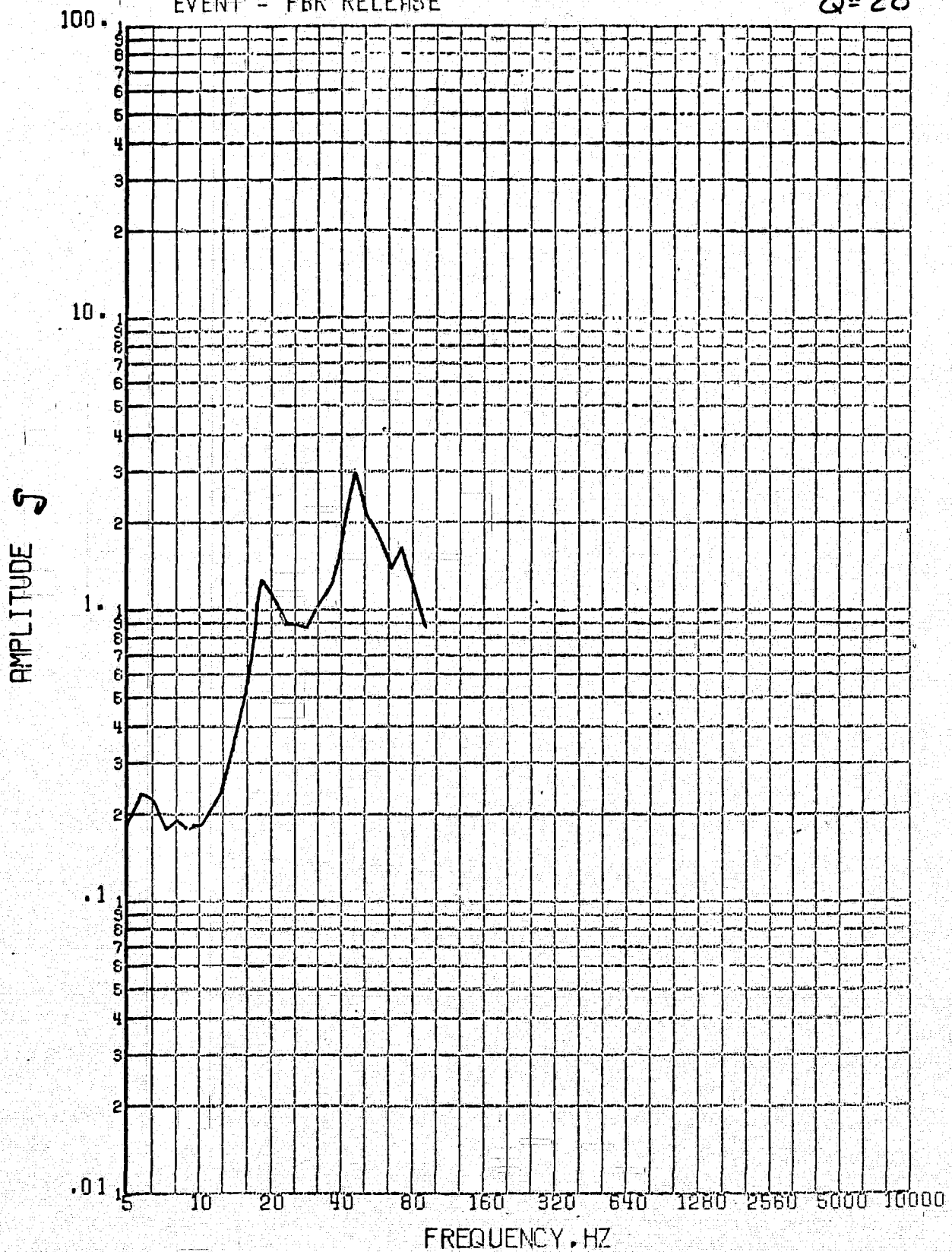
Figure 11 d

2.91

4-9-74

SENSOR - VDD3 ACCEL 5. CY205. Y
EVENT - FBR RELEASE

Q=20



2.92

Figure 11 e

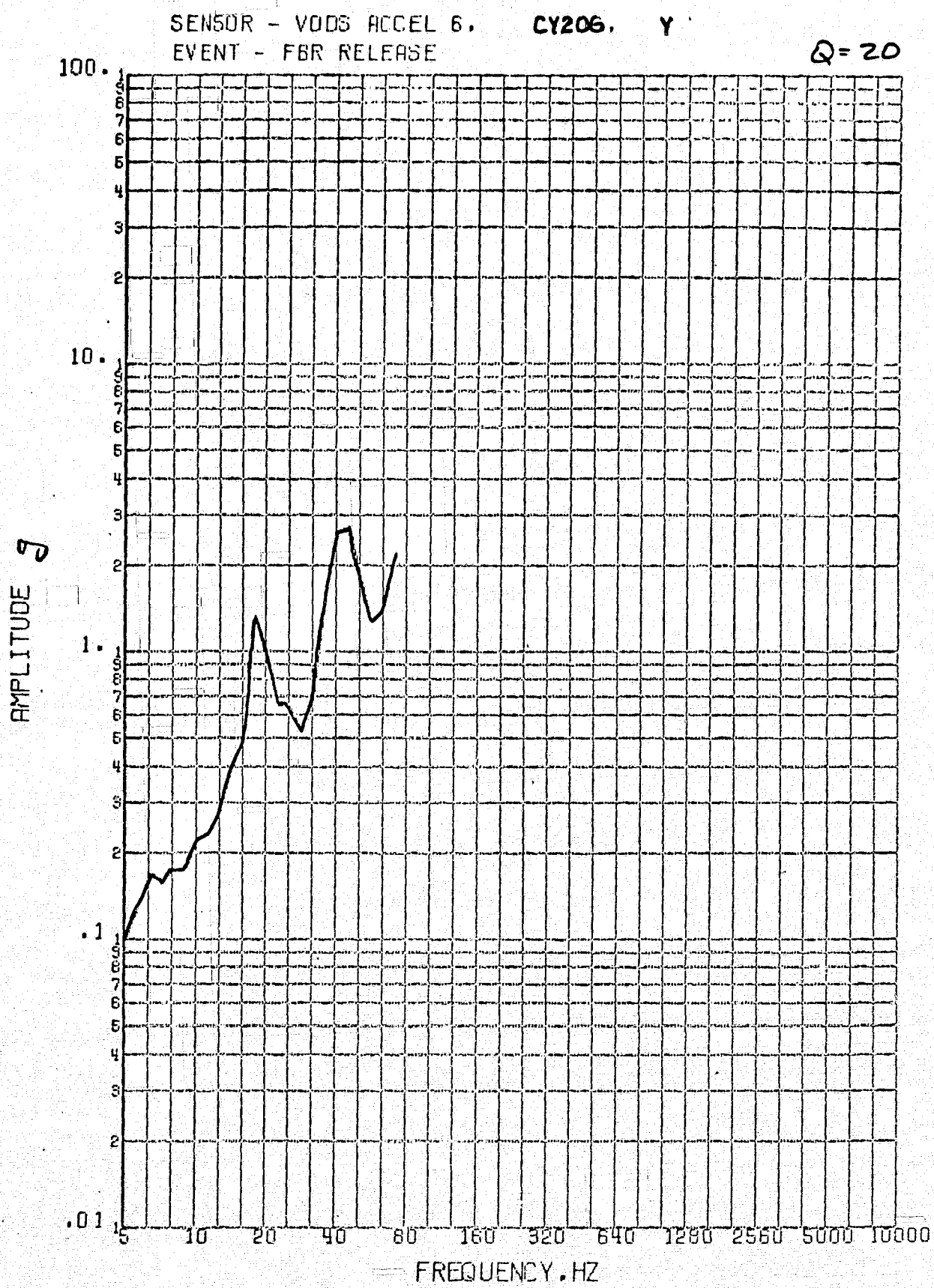


Figure 11 f

Revision A
4-9-74

SENSOR - V005 ACCEL 7, CY207. X
EVENT - FBR RELEASE

Q=20

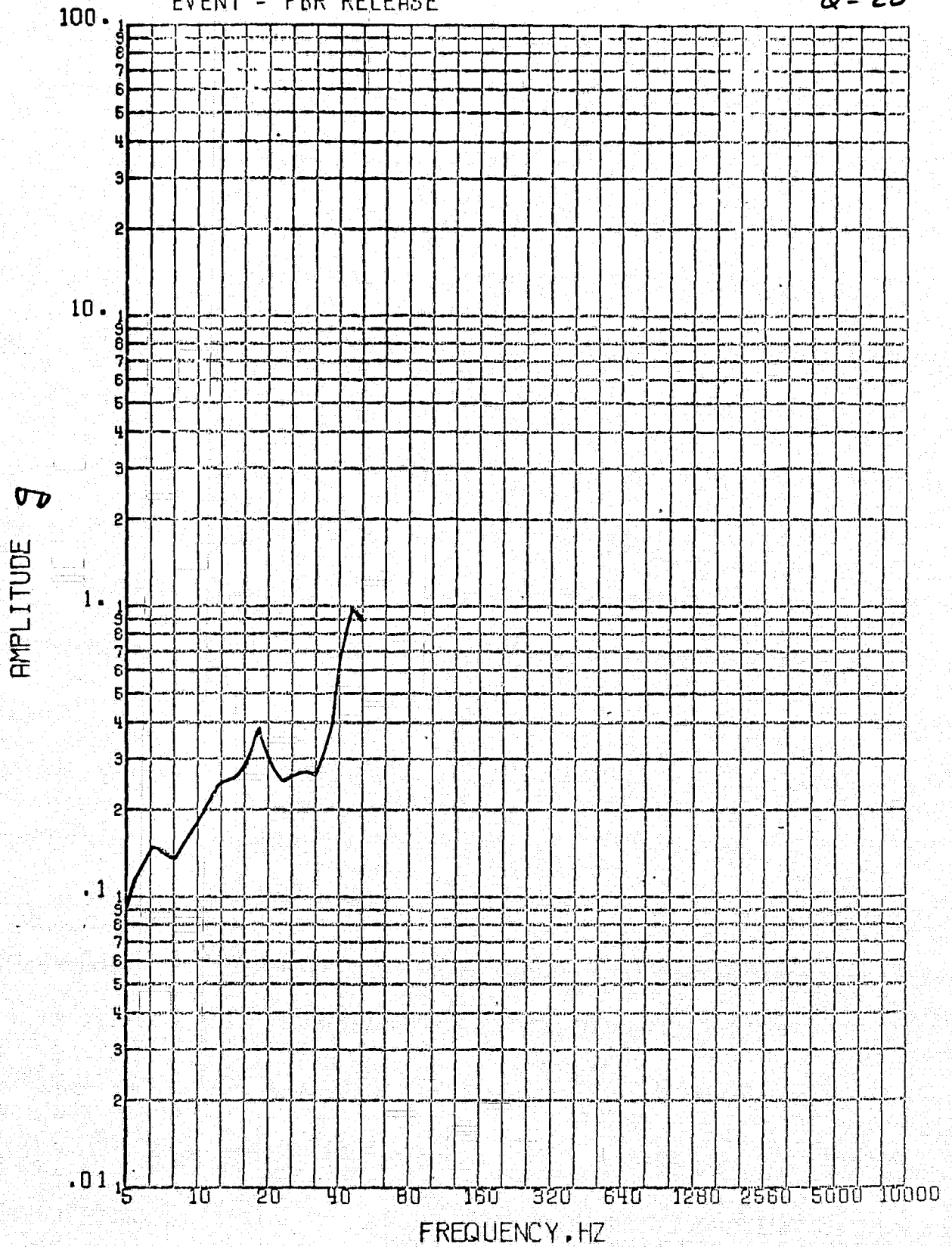
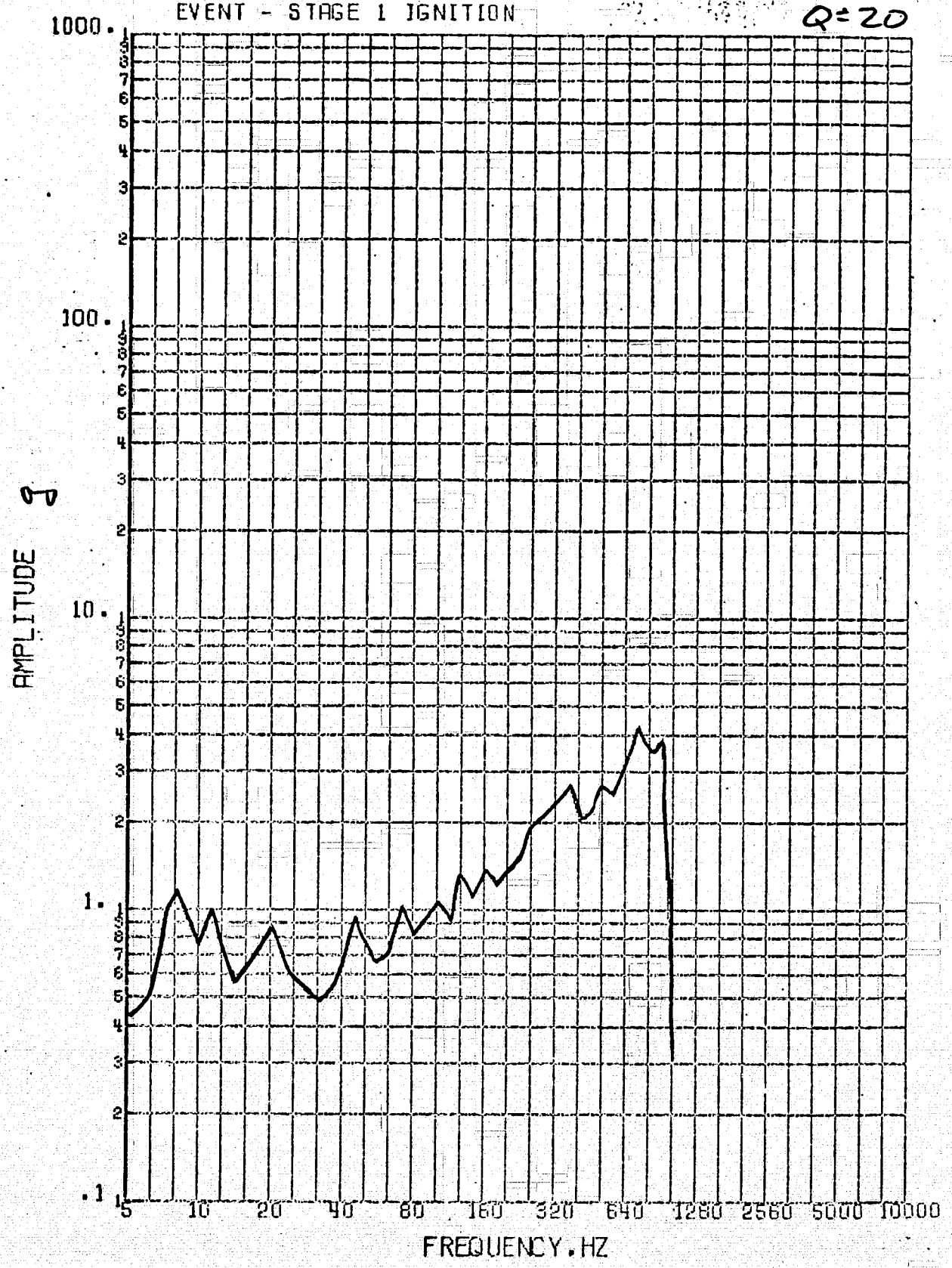


Figure 11 g

2.94

SENSOR - VDO5 ACCEL 1. CY201. 7
EVENT - STAGE 1 IGNITION

Q=20



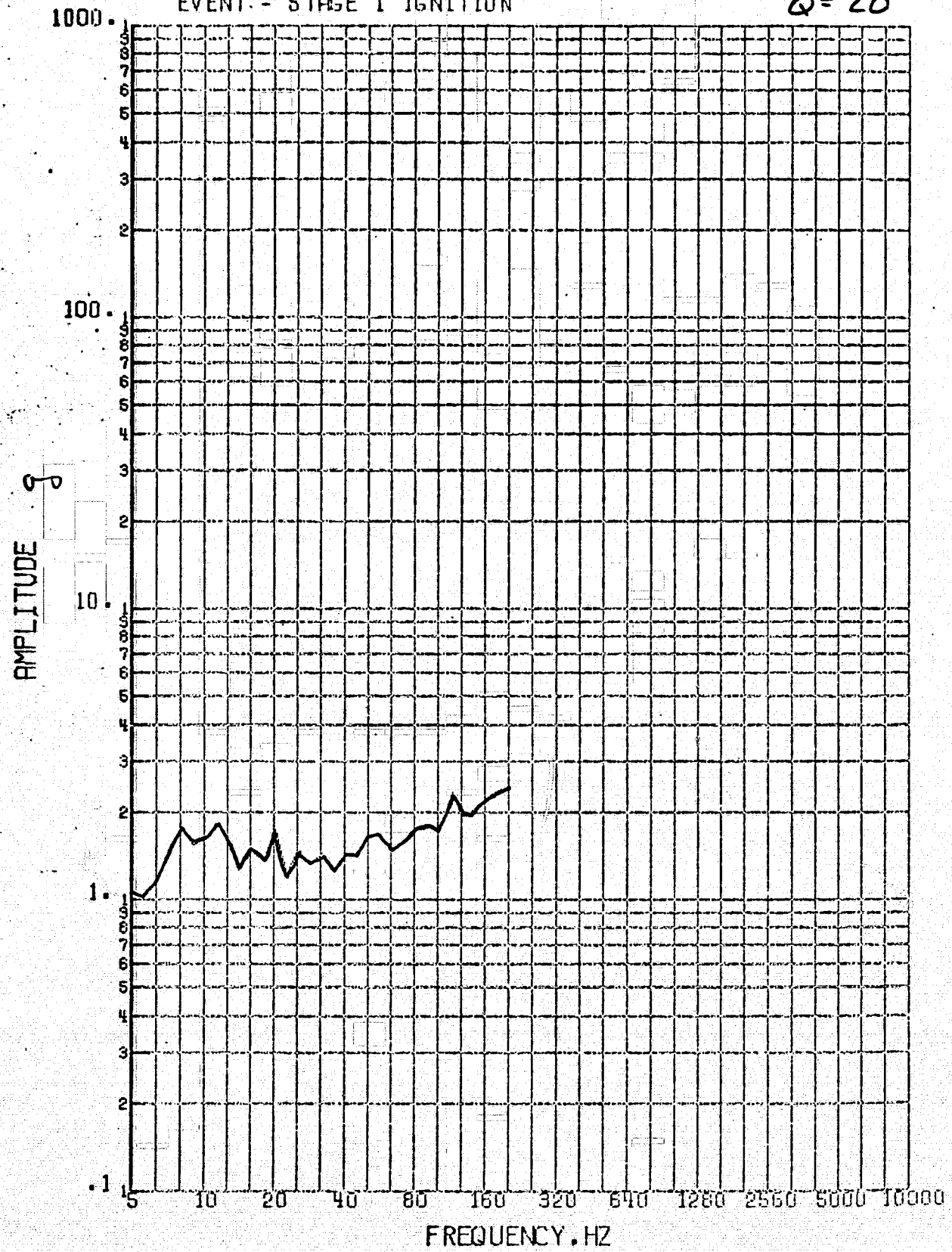
C-2

Figure 12 a

2.95

SENSOR - VDDS ACCEL 2. CY202. Z
 EVENT - STAGE 1 IGNITION

Q=20

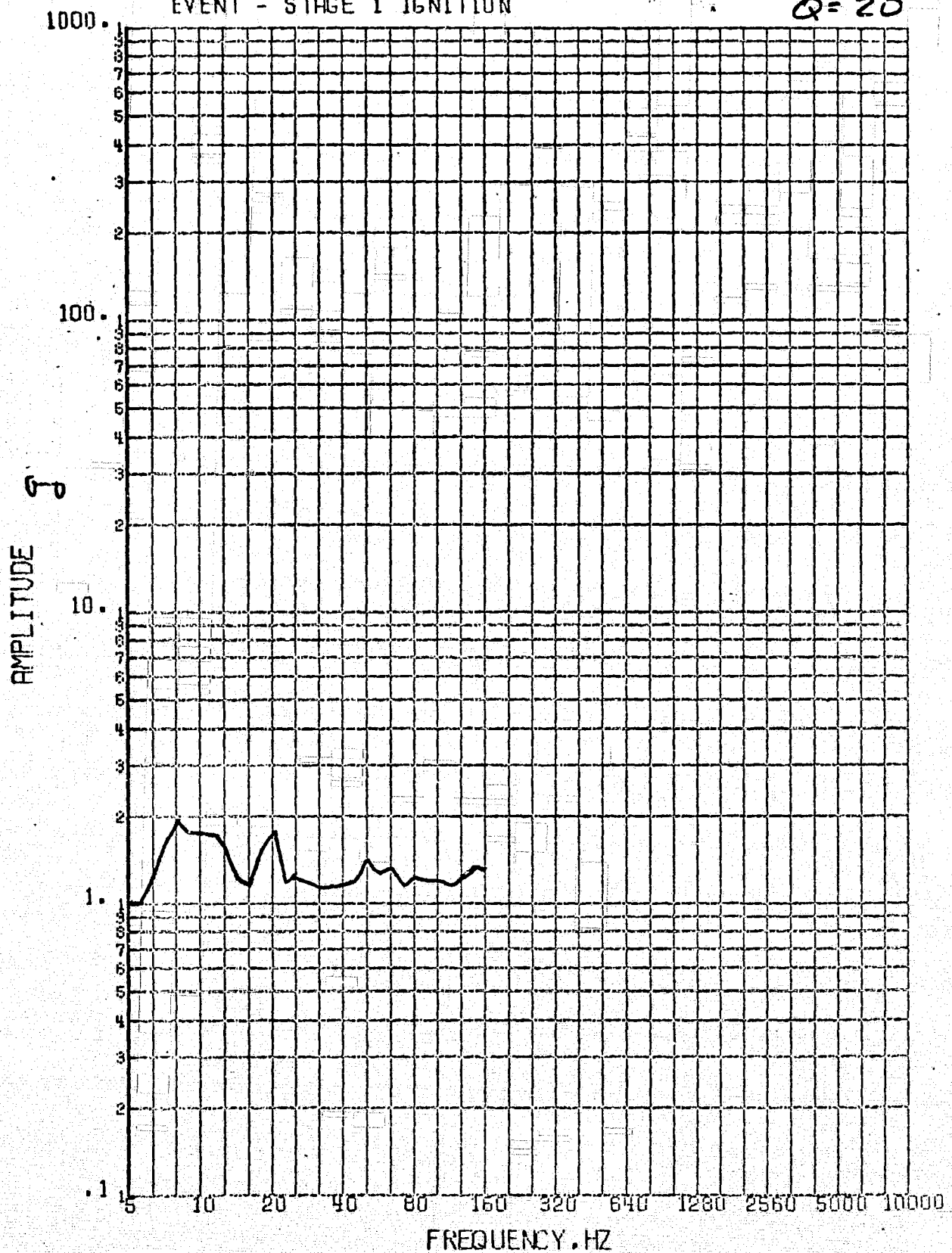


2.96

Figure 12 b

SENSOR - VOOS ACCEL 3, CY203, Z
EVENT - STAGE 1 IGNITION

Q=20

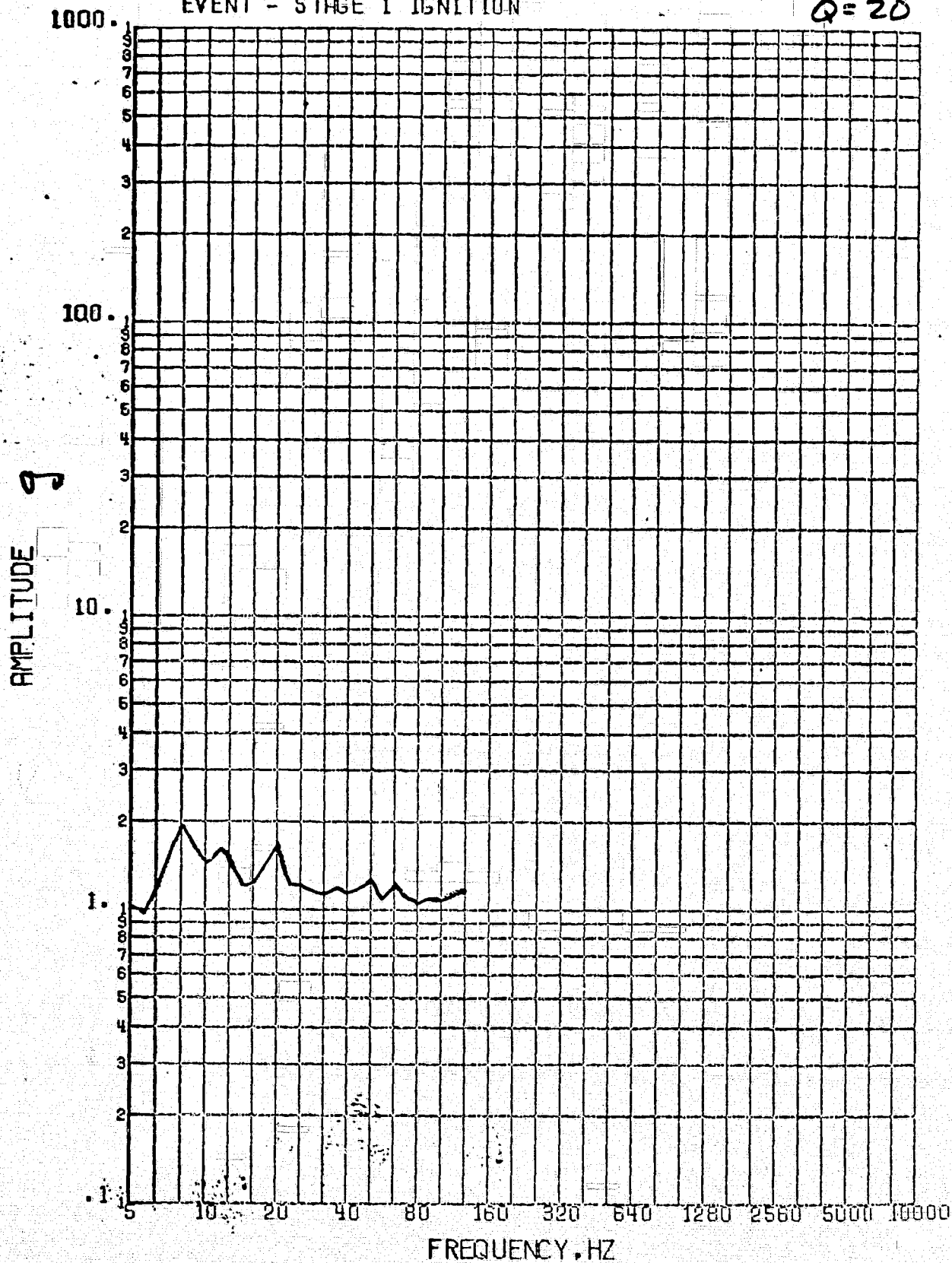


2.97

Figure 12c

SENSOR - VDDS ACCEL 4. CY204. Z
EVENT - STAGE 1 IGNITION

Q=20

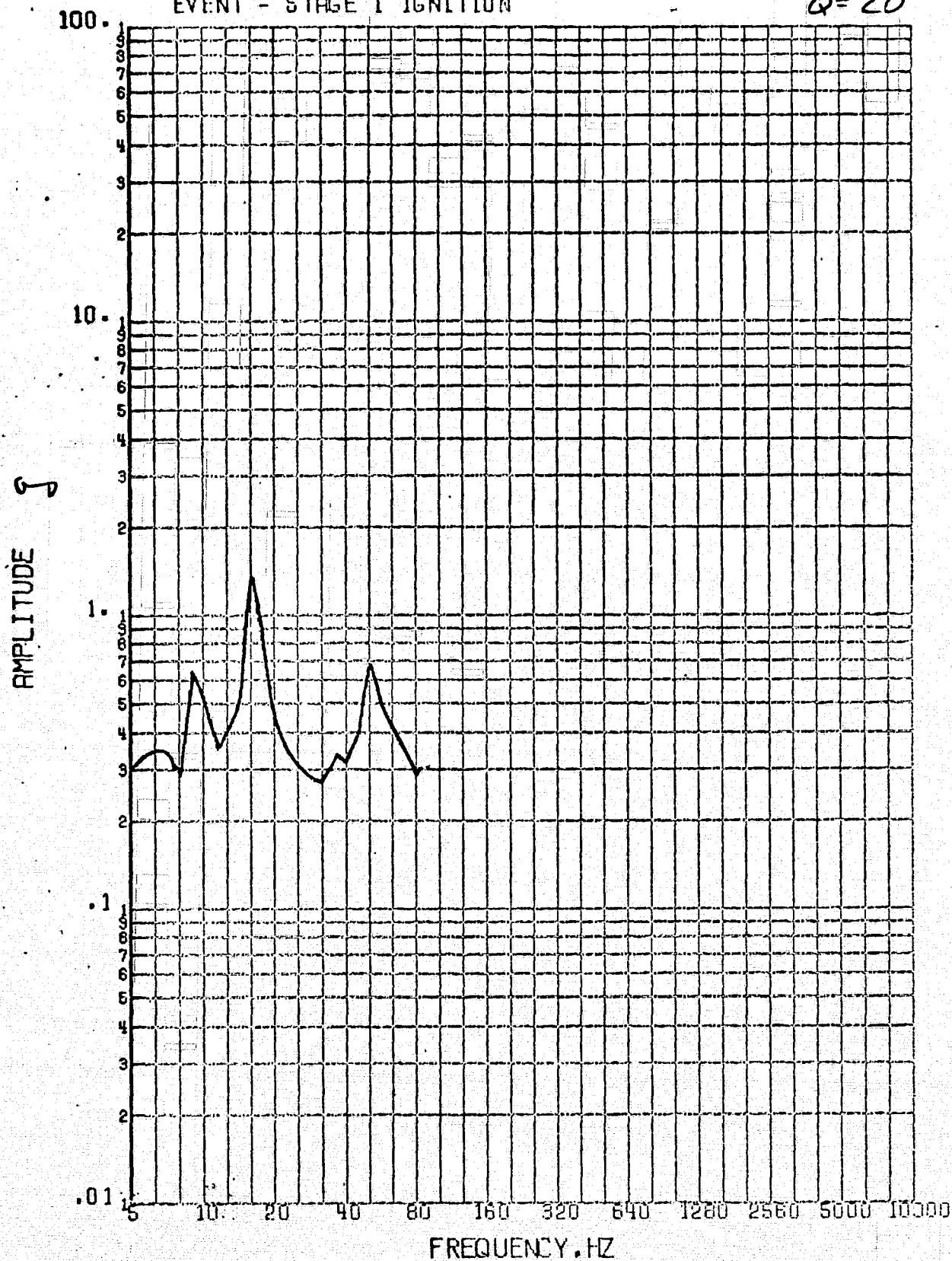


2.98

Figure 12 d

77
SENSOR - VOOS ACCEL 5, CY205. Y
EVENT - STAGE 1 IGNITION

Q=20



2.99

Figure 12e

SENSOR - VOOS ACCEL 6, CY206, Y
EVENT - STAGE 1 IGNITION

Q=20

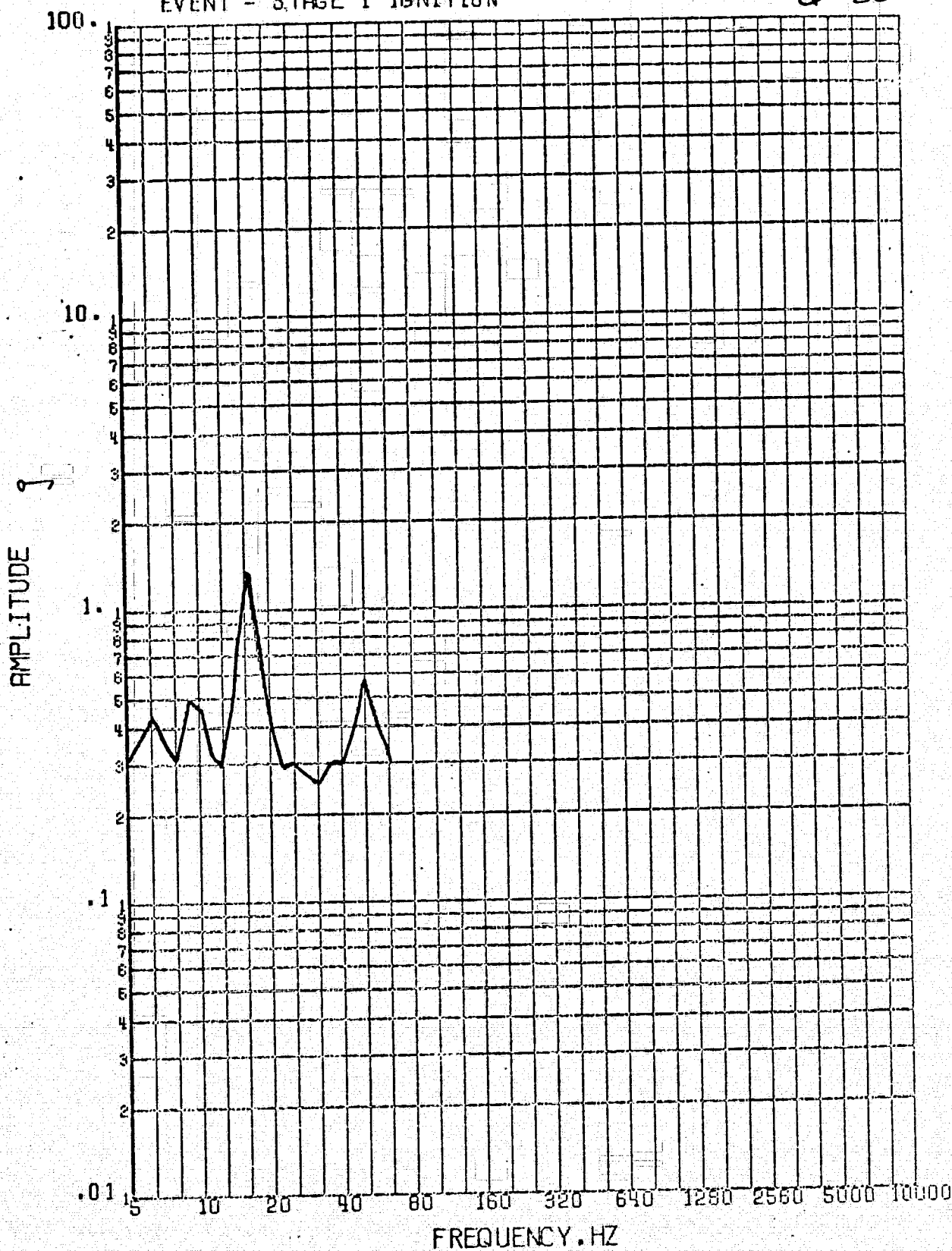
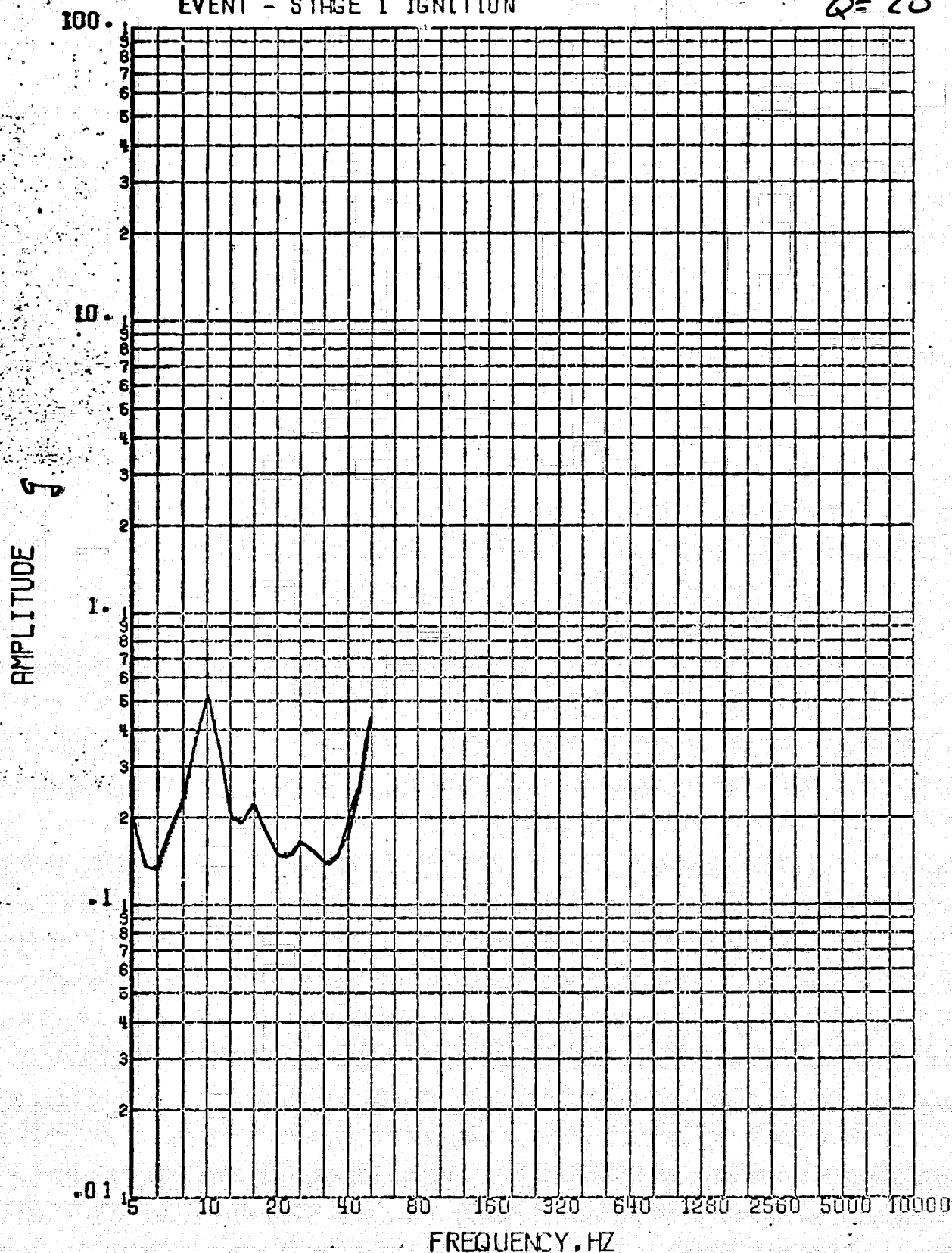


Figure 12 f

SENSOR - VODS ACCEL 7, CY207, X
EVENT - STAGE 1 IGNITION

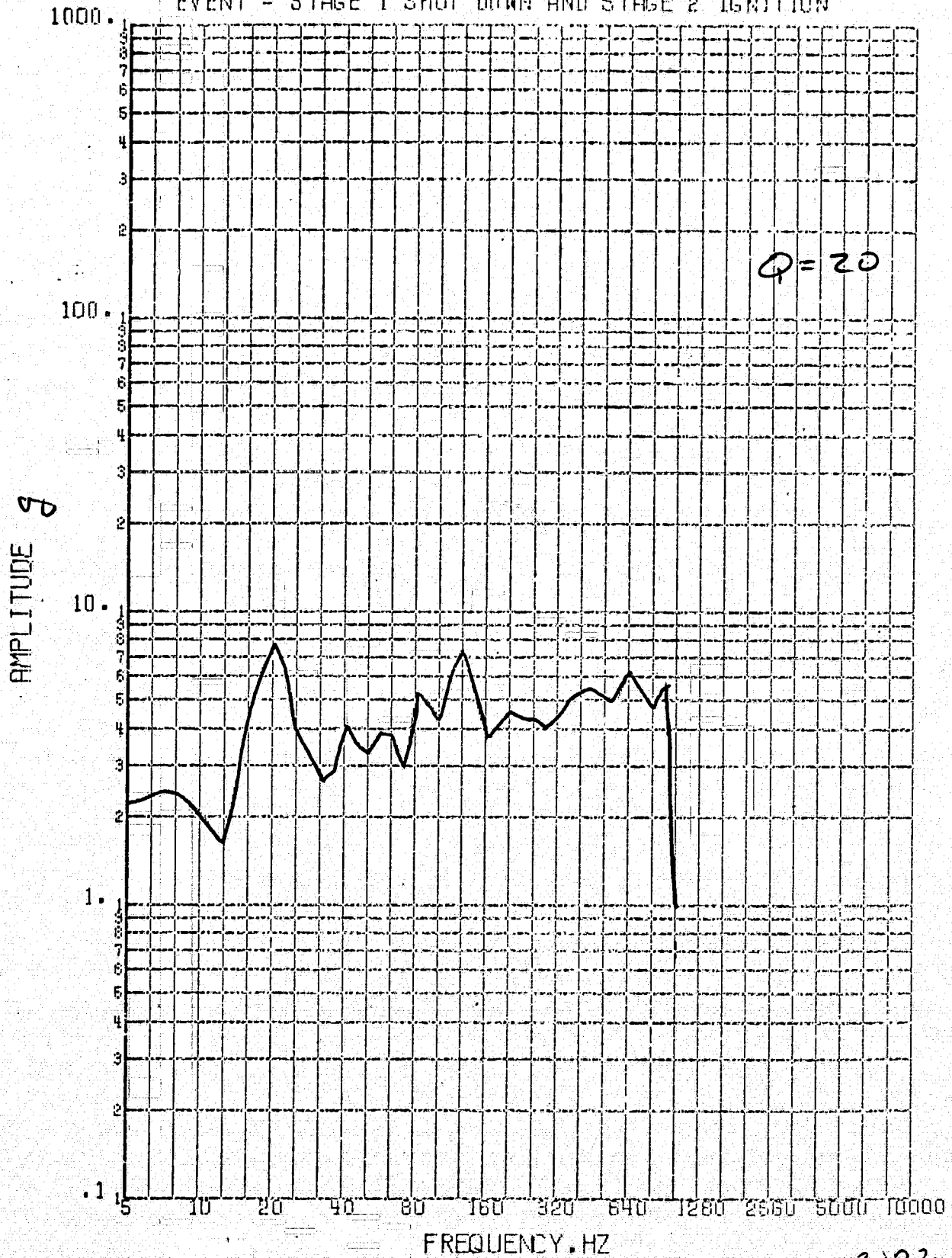
Q=20



2.101

Figure 12 g

SENSOR - VDO5 ACCEL 1. CY201. 2
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION



2.102

Figure 13a

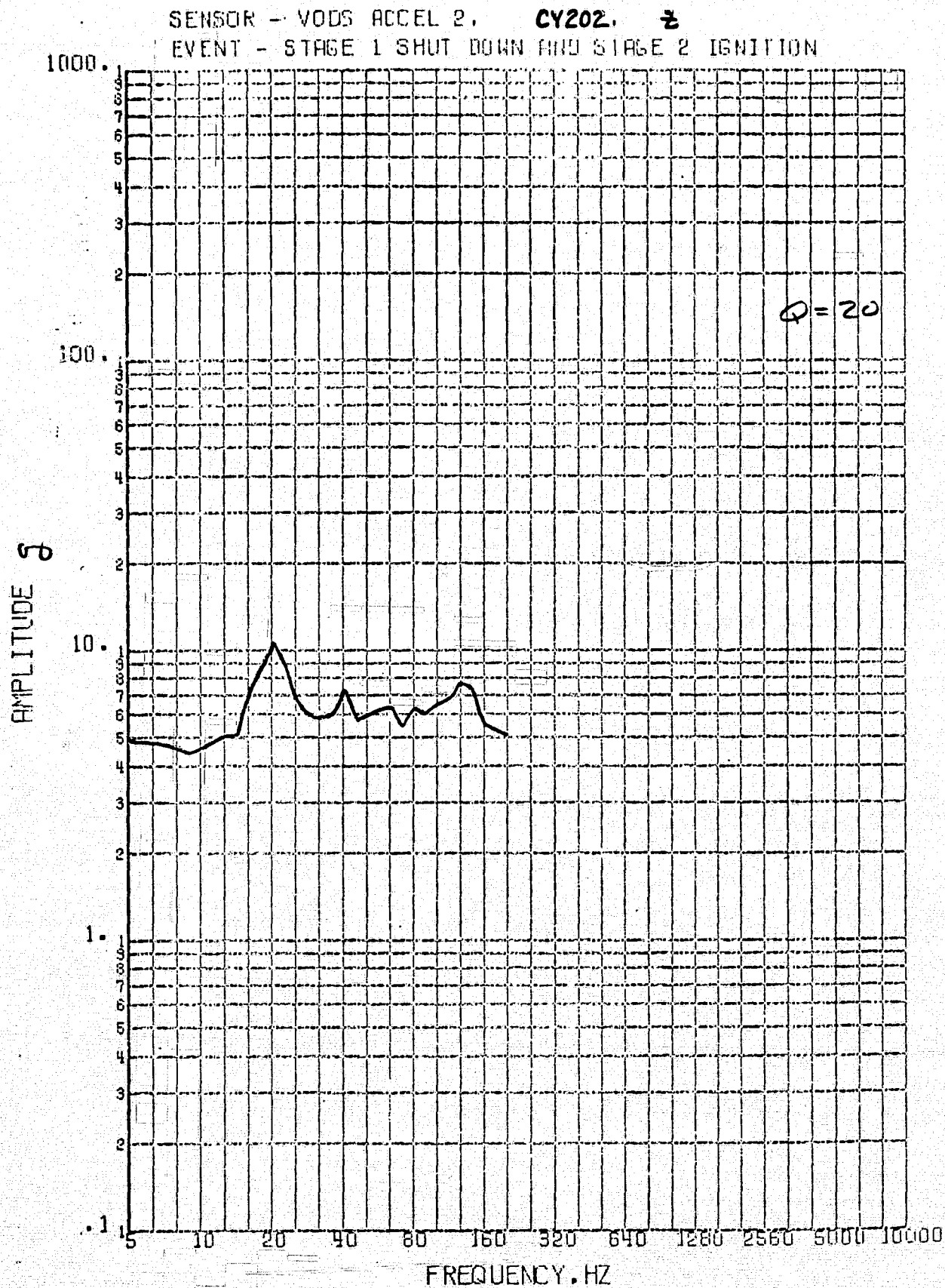


Figure 13 b

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Revision A
4-9-74

104

SENSOR - VDD6 ACCEL 3, CY203, 2
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

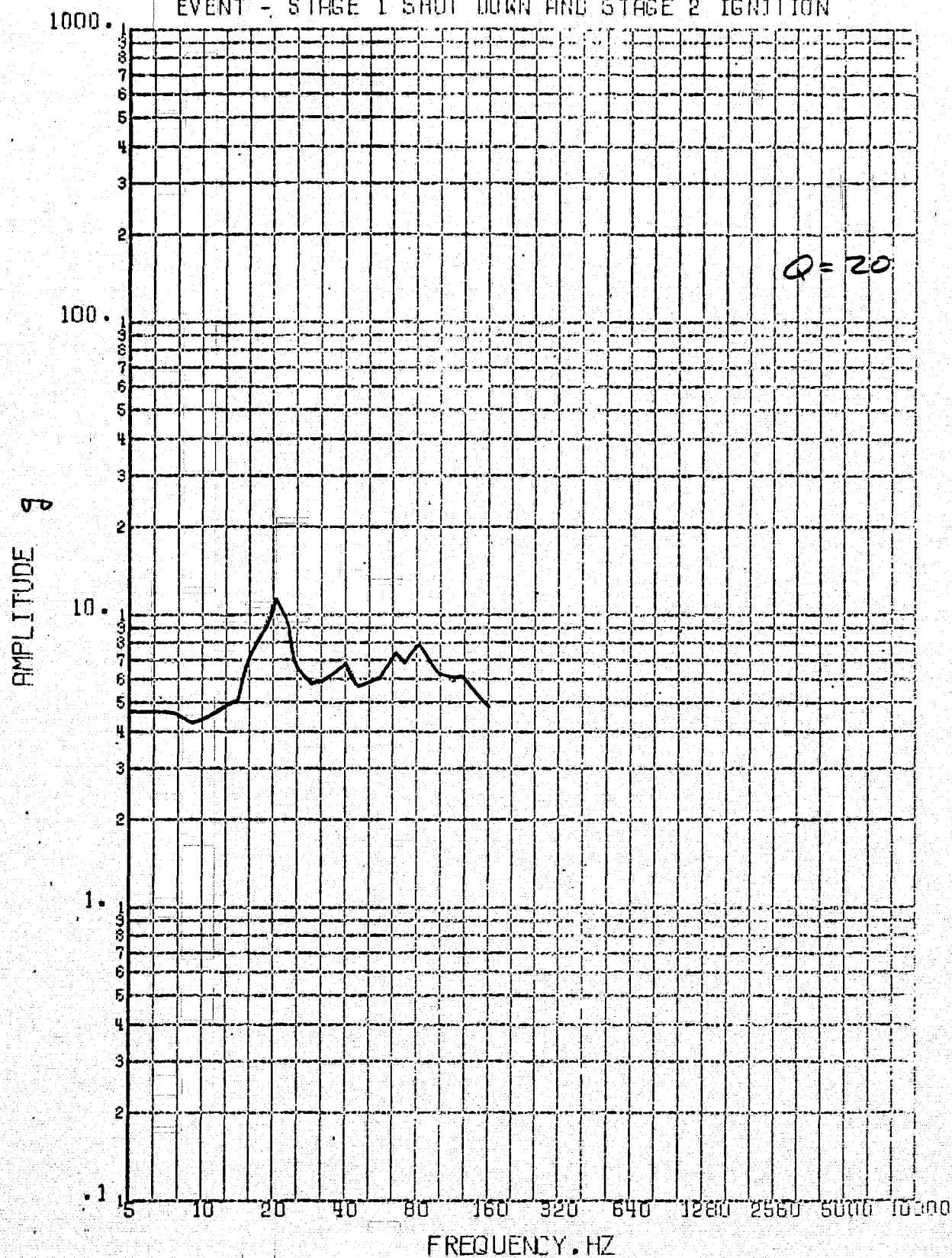


Figure 13c

2.104

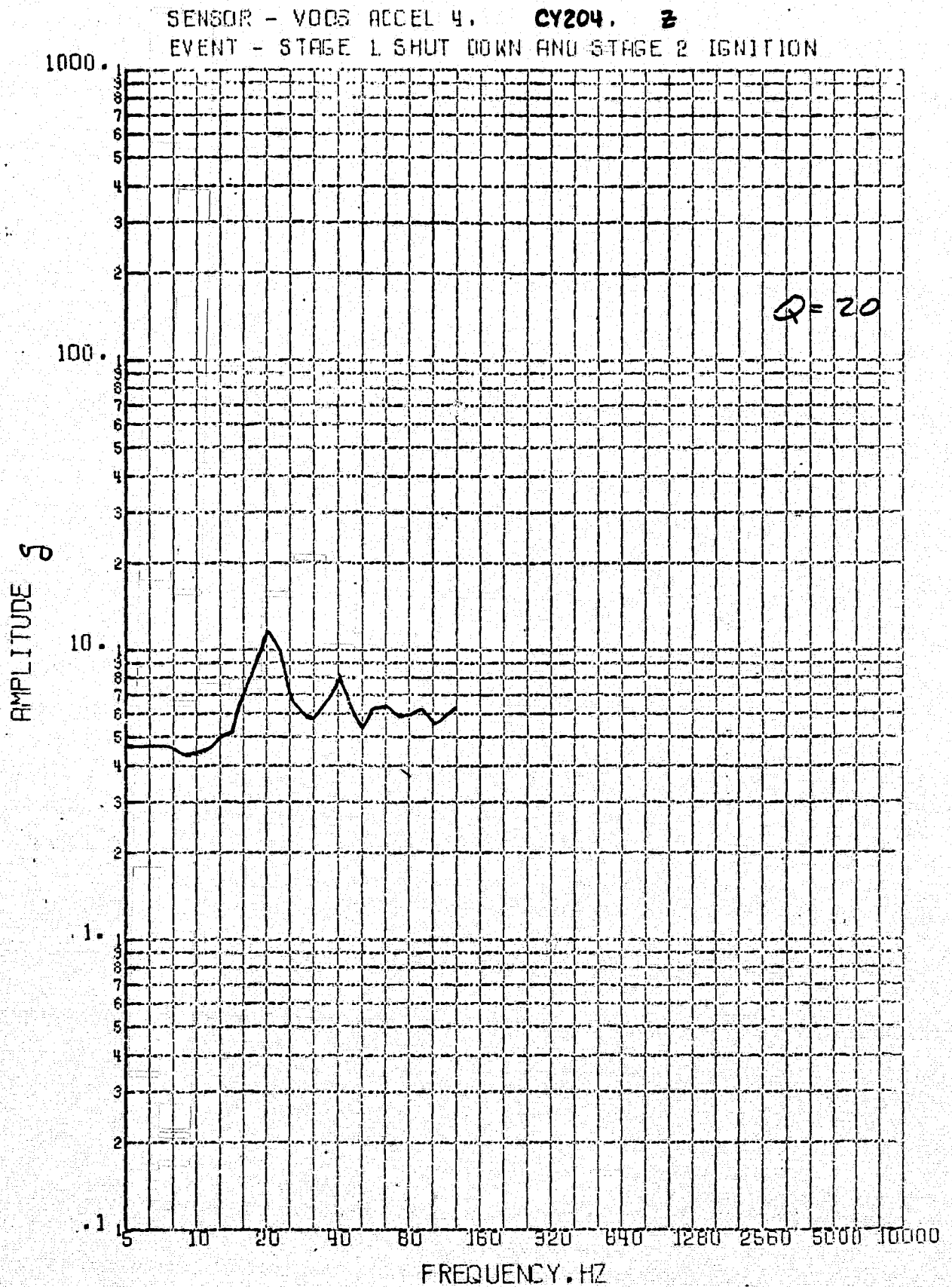


Figure 13 d

SENSOR - V005 ACCEL 5. CY205. Y
EVENT - STAGE 1 SHUT DOWN AND STAGE 2 IGNITION

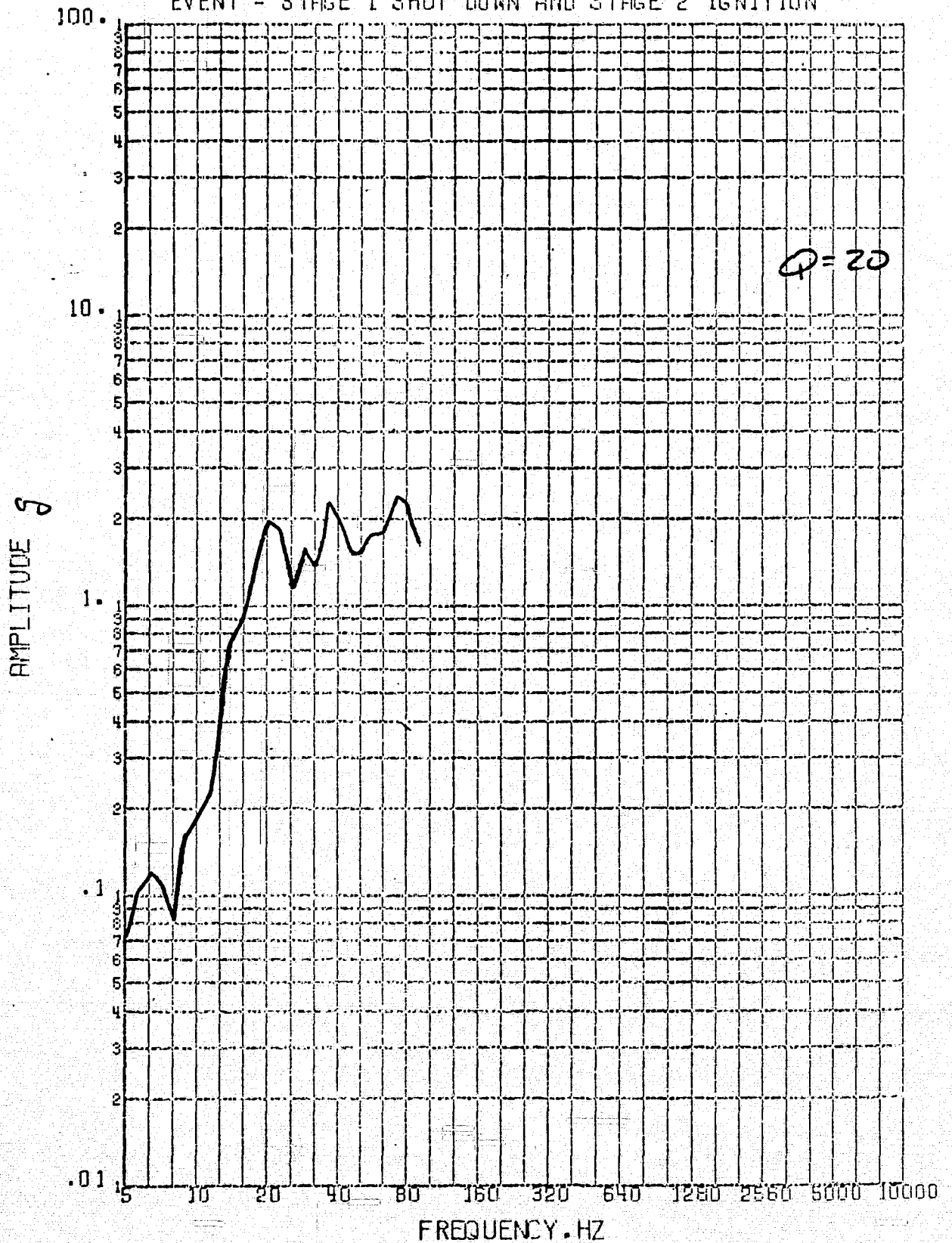


Figure 13 e

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Revision A 107
4-9-74

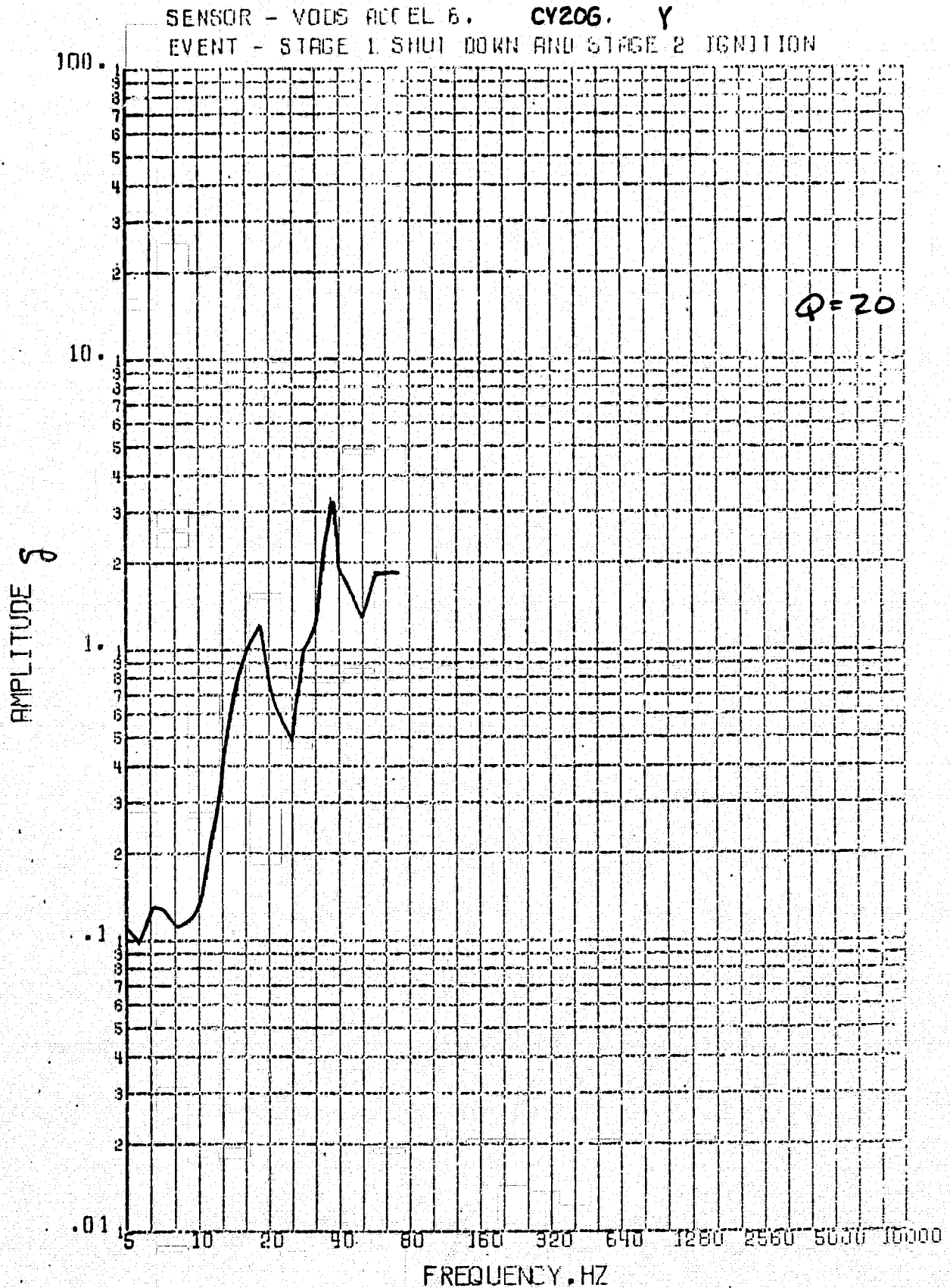


Figure 13 f

2.107

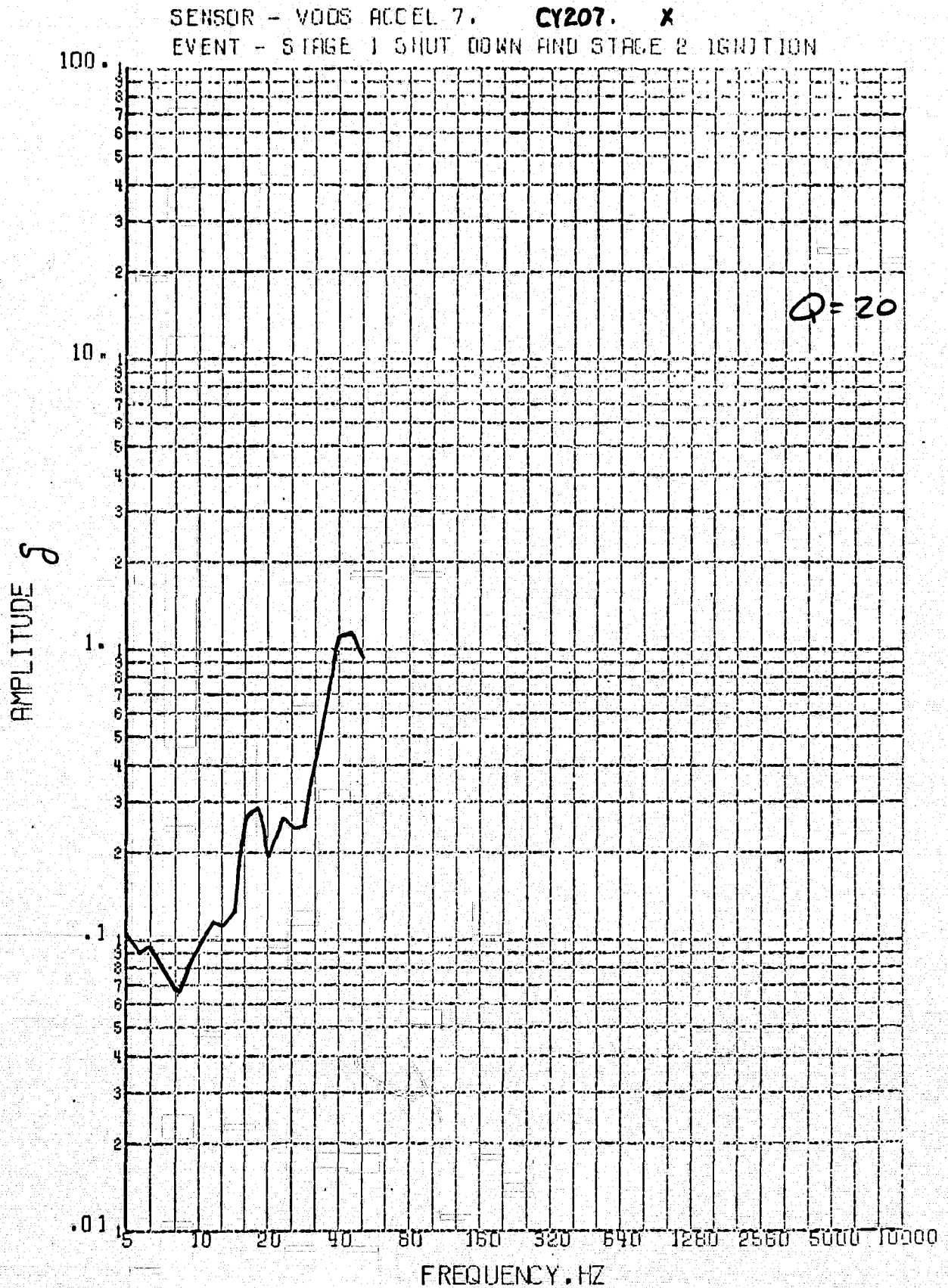
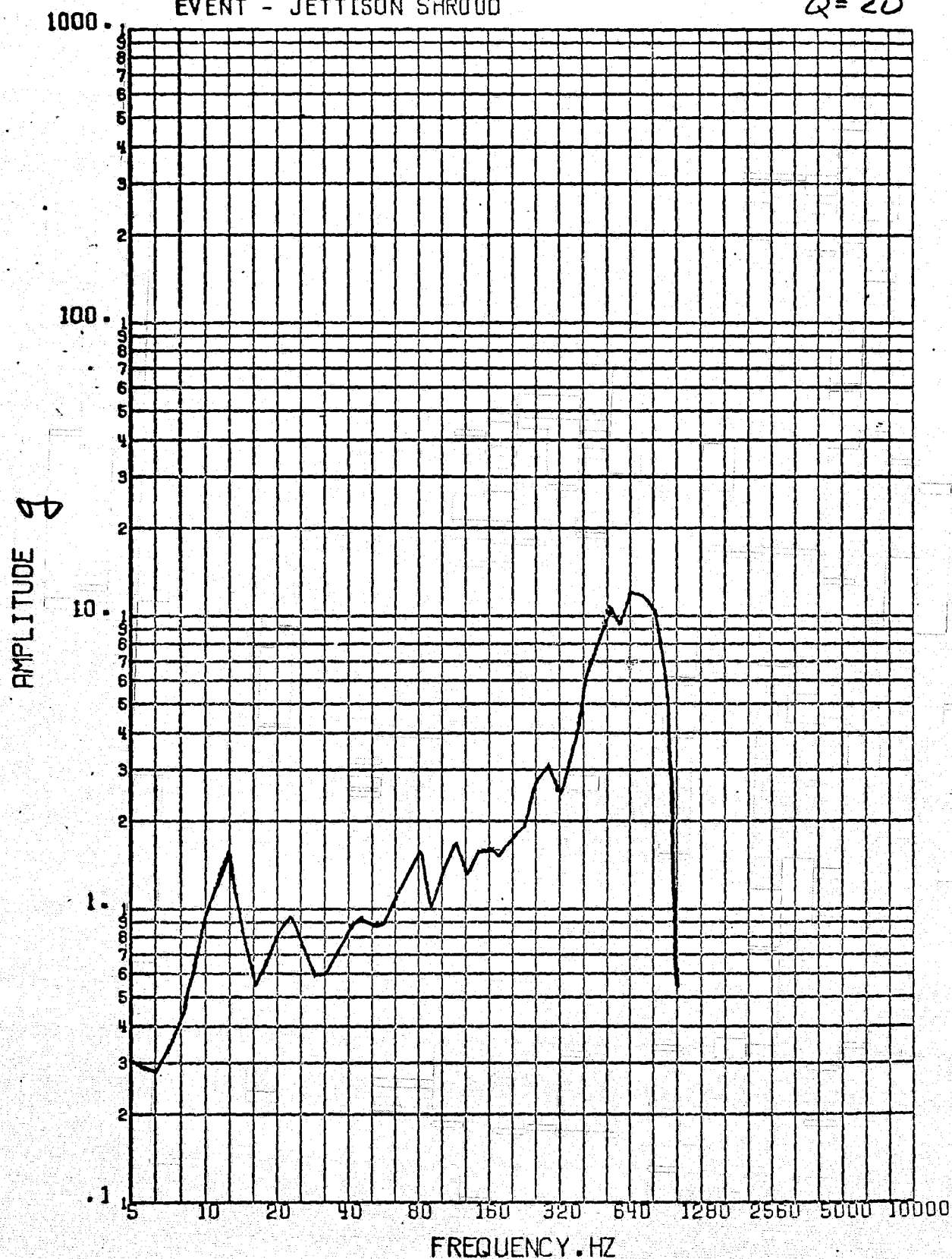


Figure 13 g

SENSOR - VOOS ACCEL 1. CY201. Z
EVENT - JETTISON SHROUD

Q=20



- Figure 14 a

SENSOR - VOOS ACCEL 2. CY202. Z
EVENT - JETTISON SHROUD

Q=20

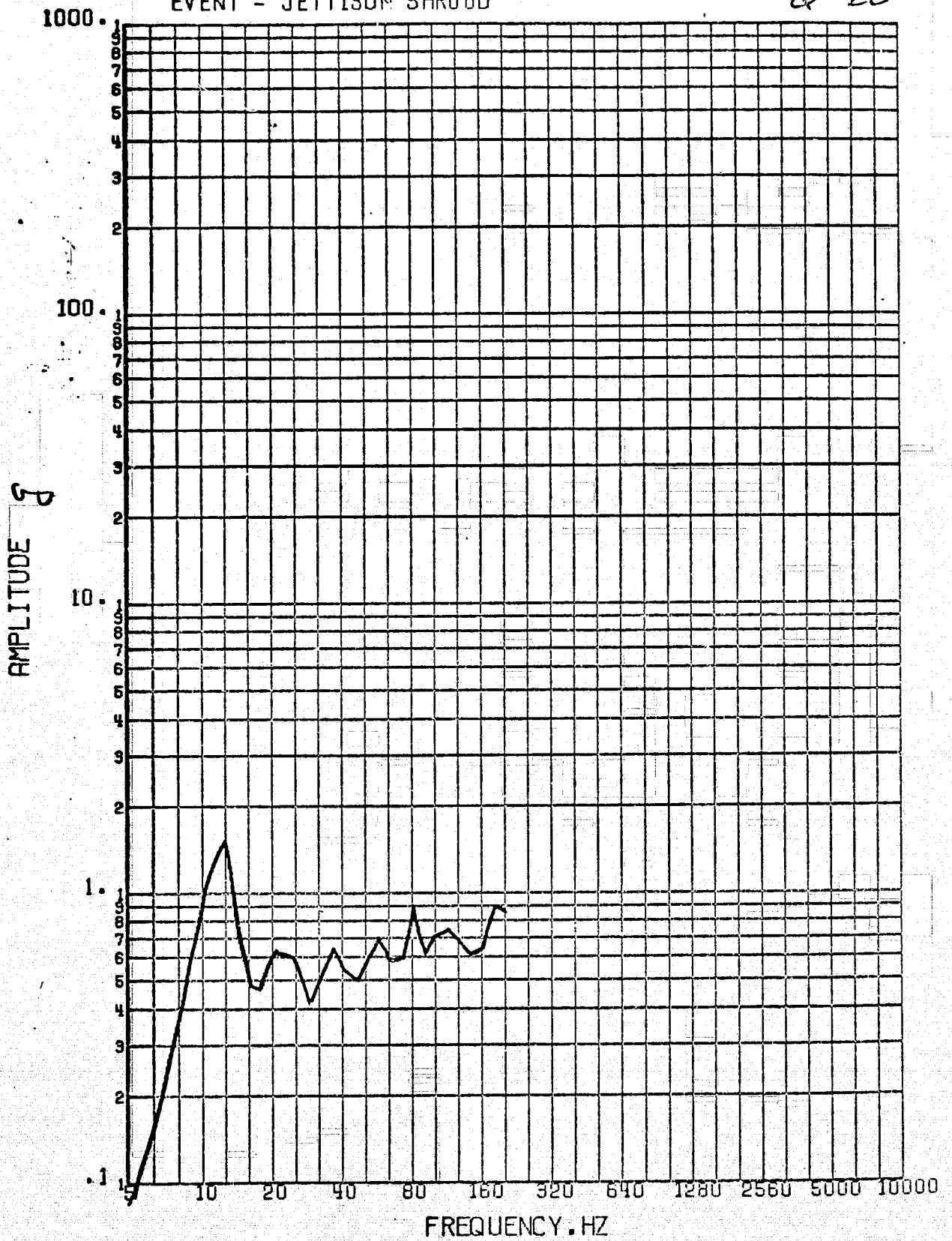
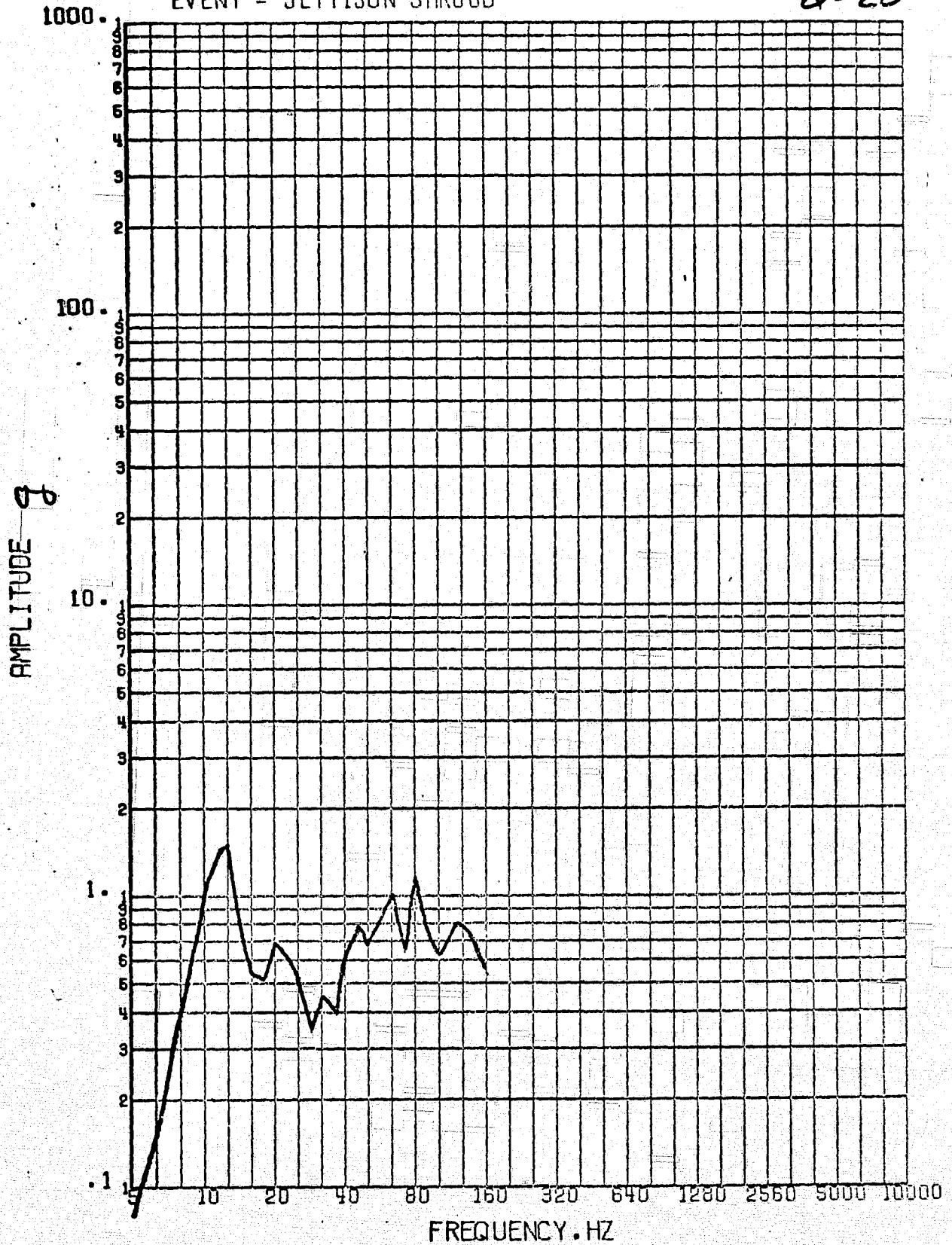


Figure 14 b

SENSOR - VODS ACCEL 3.
EVENT - JETTISON SHROUD

CY203. Z

Q=20

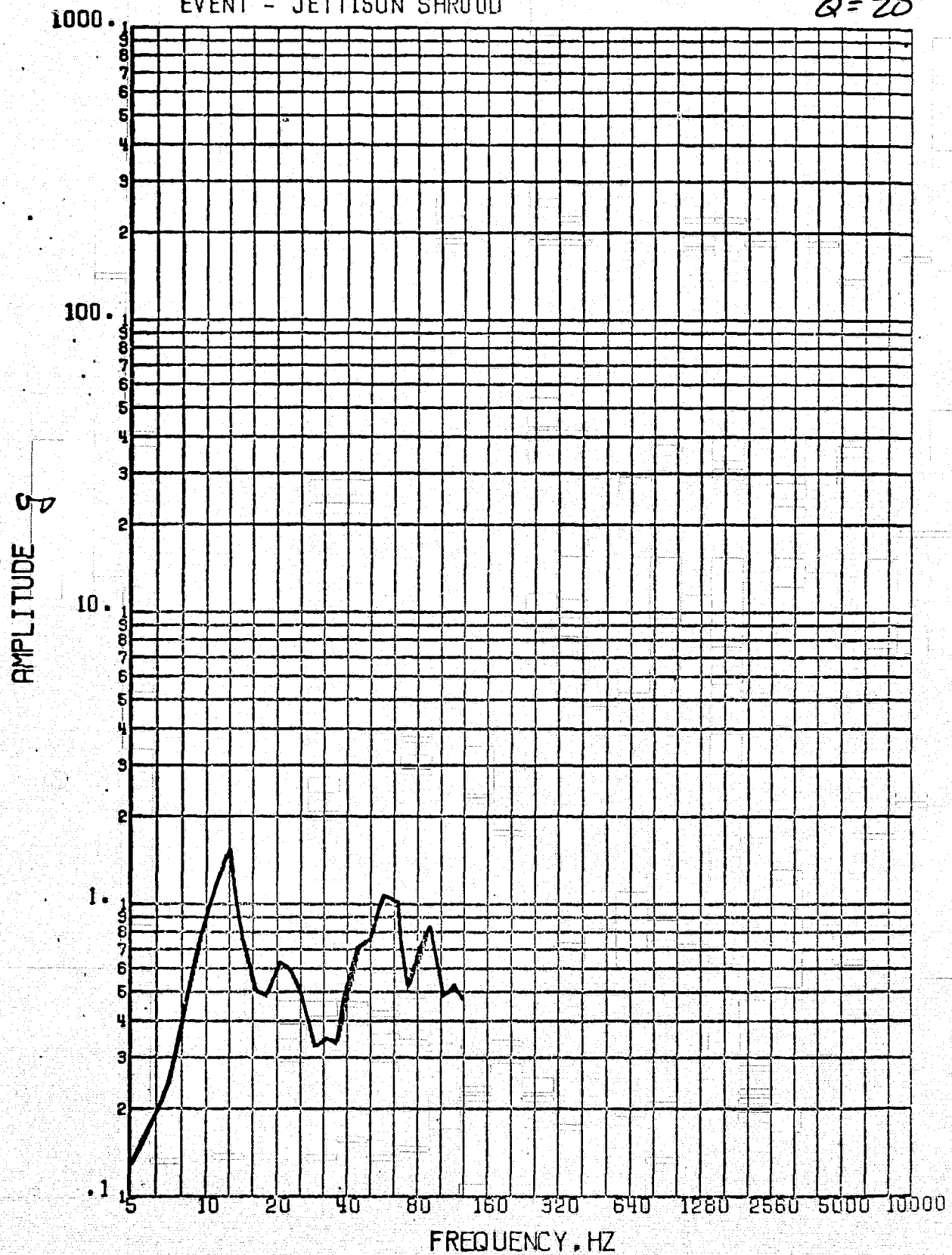


- Figure 14 c

SENSOR - VODS ACCEL 4.
EVENT - JETTISON SHROUD

CY204. Z

Q=20



- Figure 14 d

2.112

SENSOR - VOOS ACCEL 5. CY205. Y
EVENT - JETTISON SHROUD

Q = 20

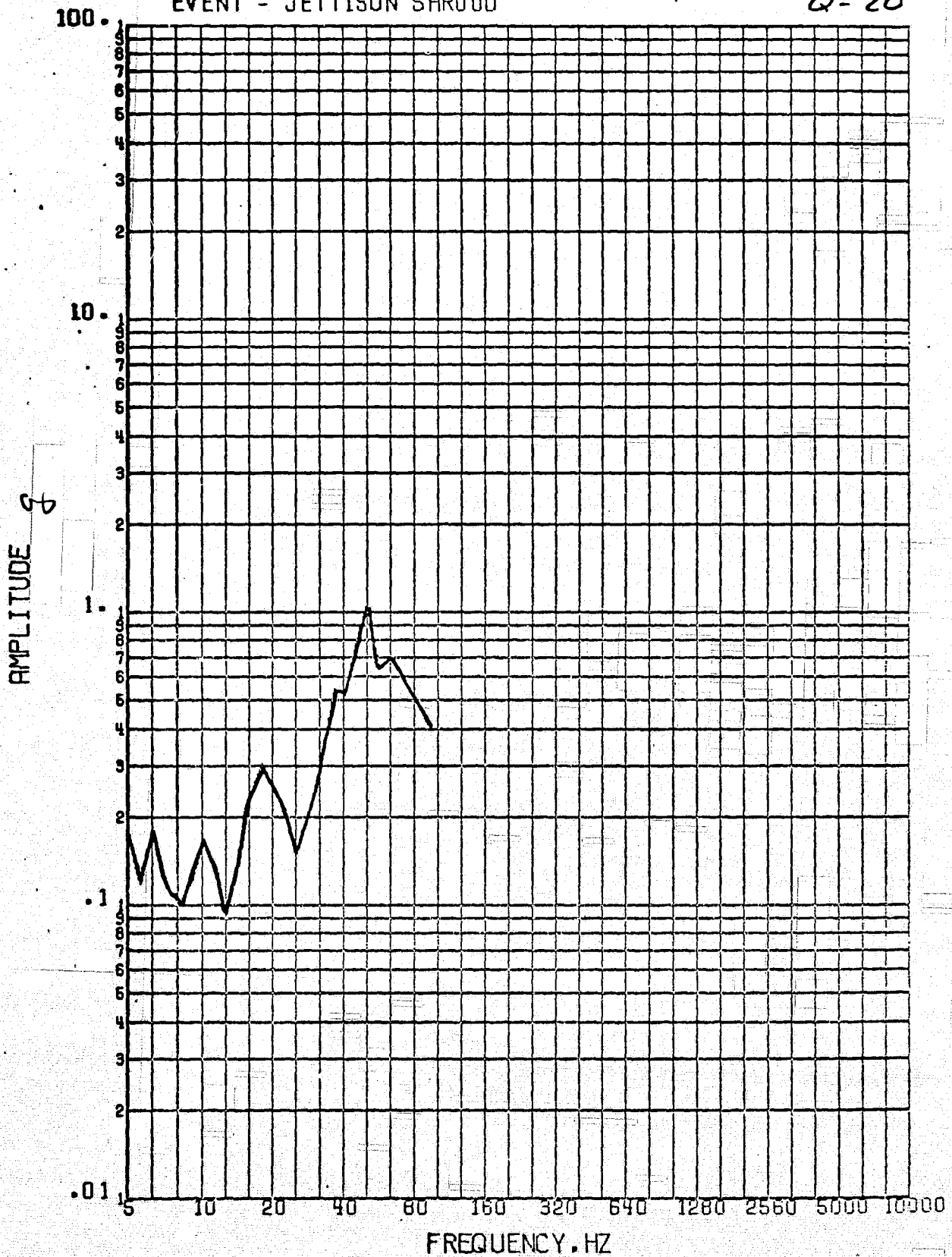


Figure 14e

2.113

SENSOR - VDO5 ACCEL 6, CY206, Y
EVENT - JETTISON SHROUD

Q = 20

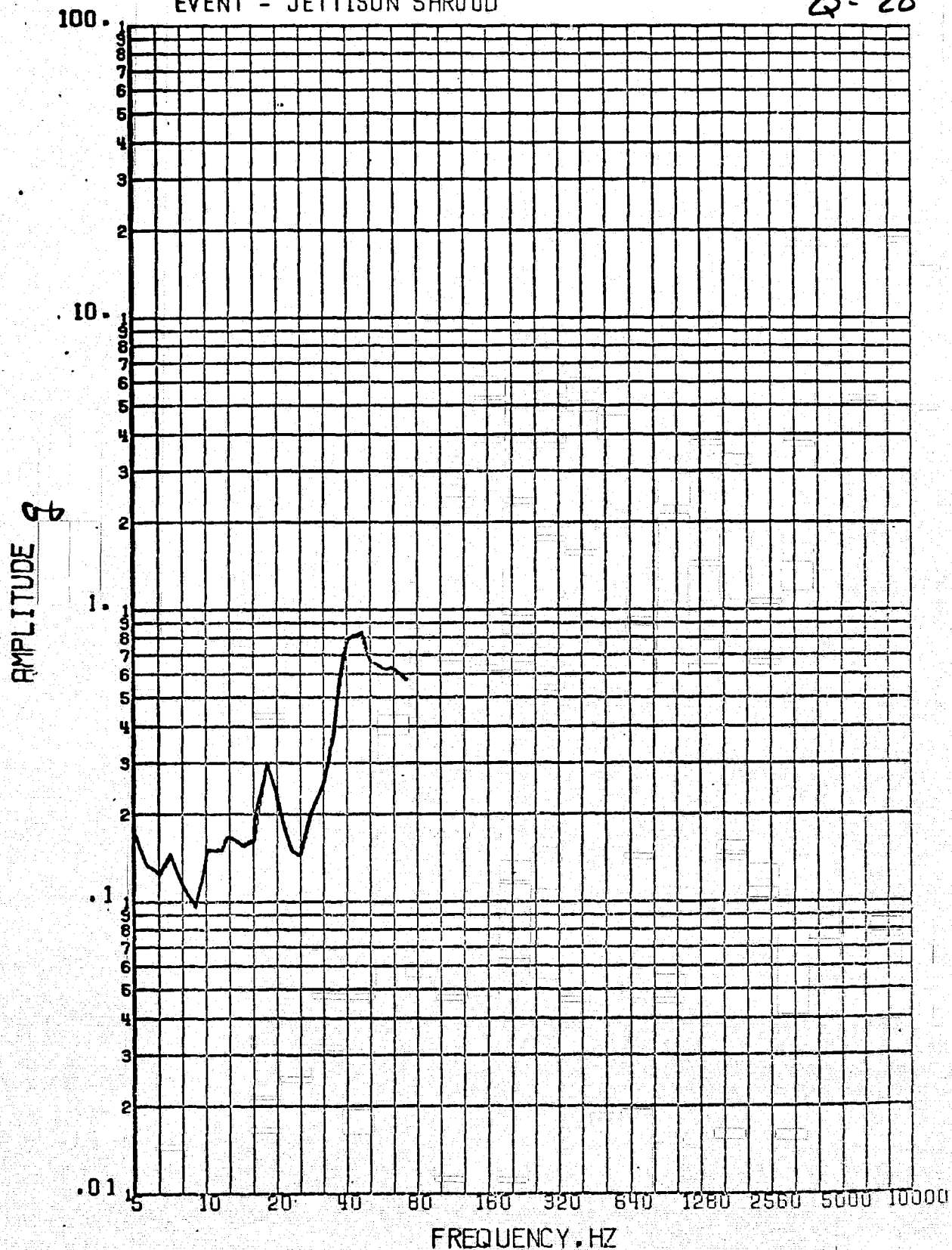
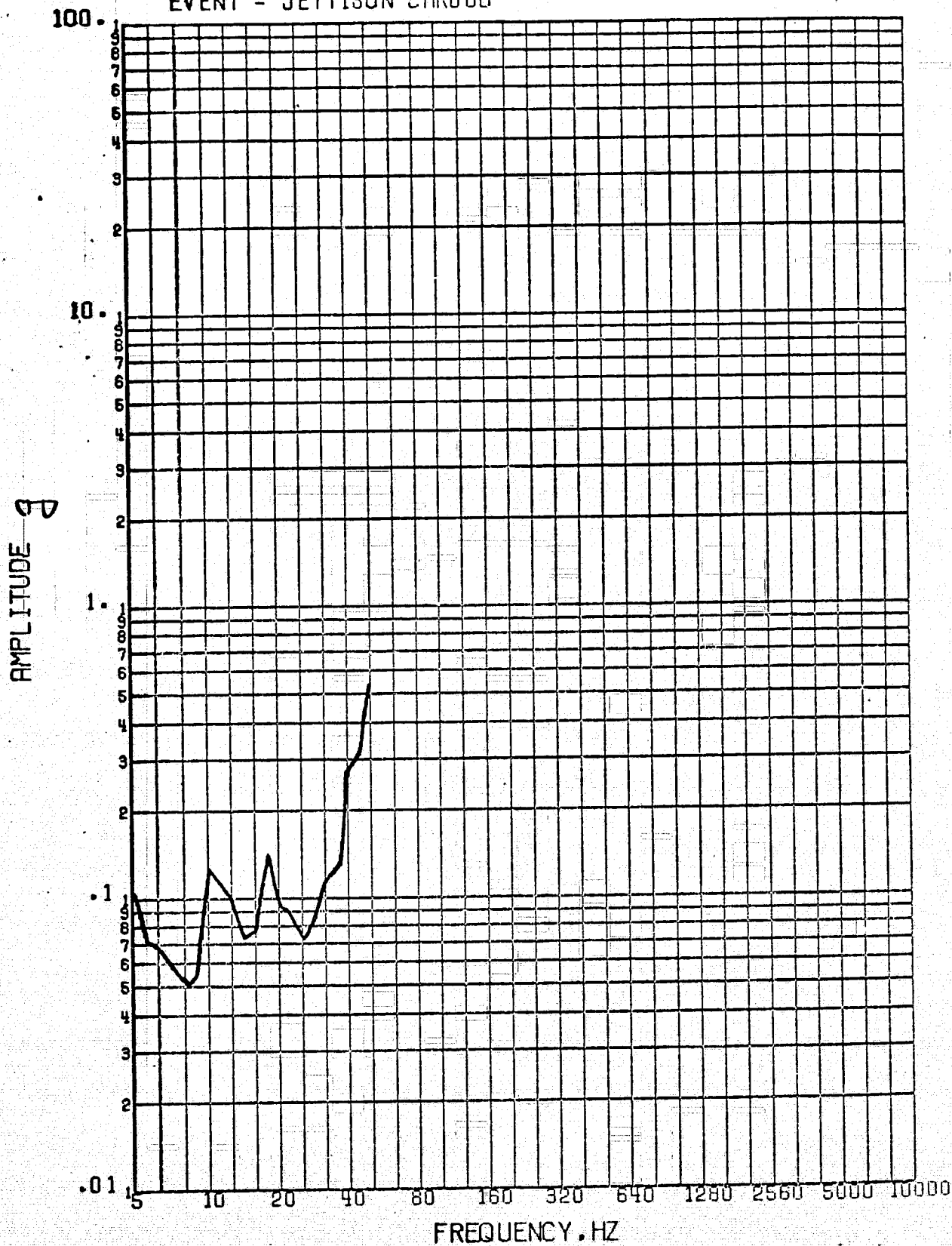


Figure 14 f

SENSOR - VODS ACCEL 7. CY207. X
EVENT - JETTISON CHROUD

Q=20



- Figure 14 g

2.115

SENSOR - VDDS ACCEL 1, CY201, 2
EVENT - STAGE 2 SHUTDOWN

Q=20

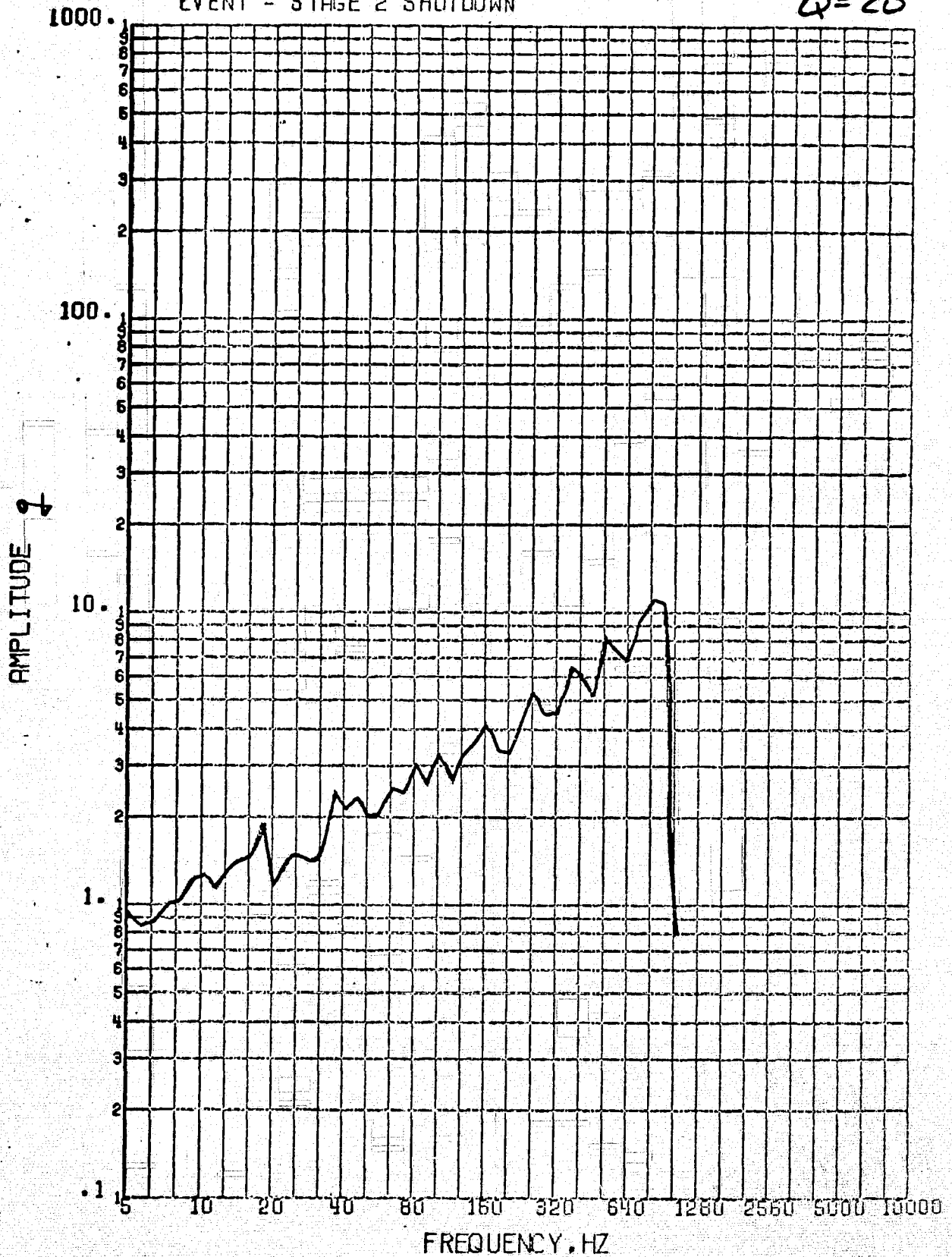
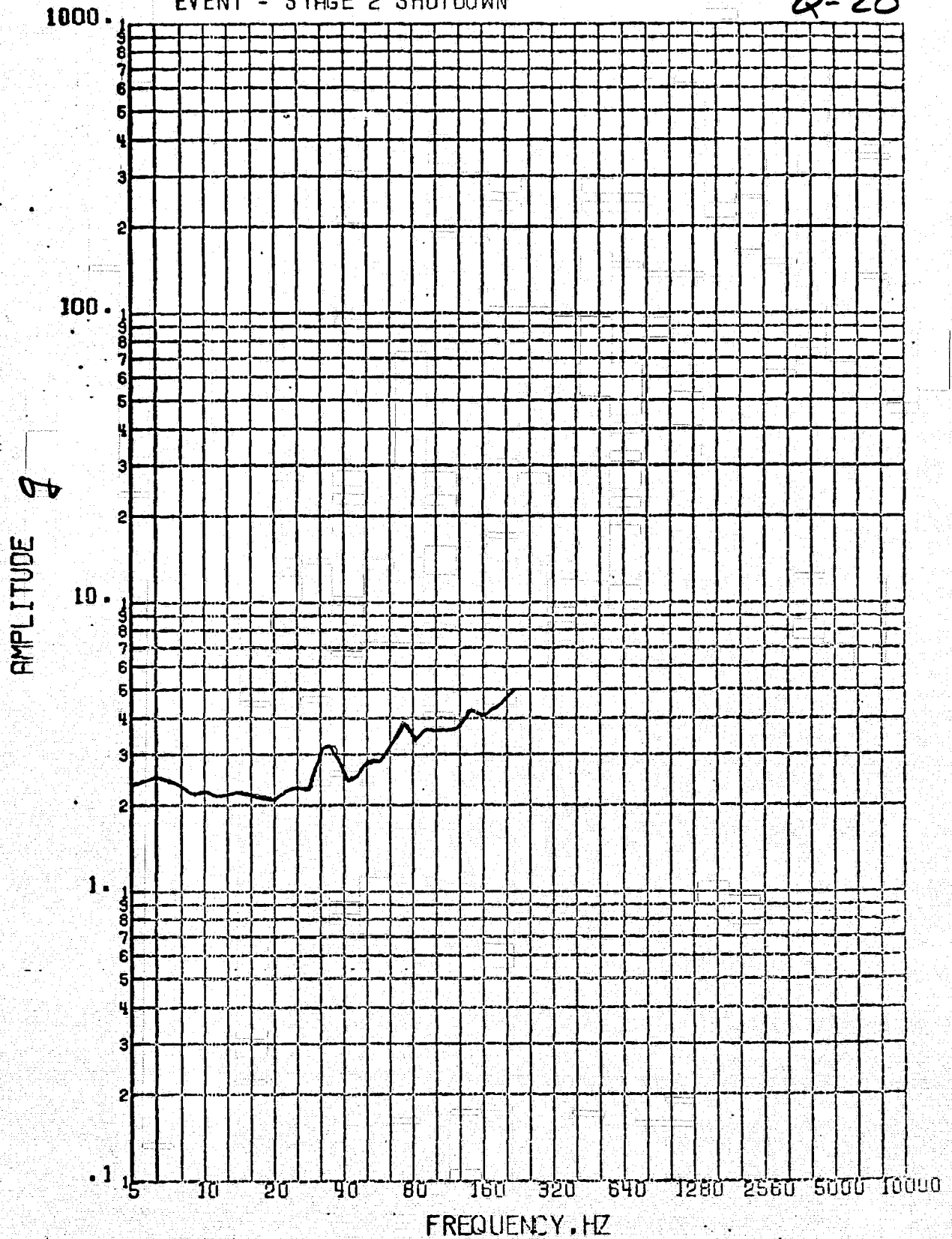


Figure 15 a

SENSOR - VDDS ACCEL 2, CY202, Z
EVENT - STAGE 2 SHUTDOWN

Q=20



2.117

Figure 15b

SENSOR - V005 ACCEL 3. CY203. Z
EVENT - STAGE 2 SHUTDOWN

Q=20

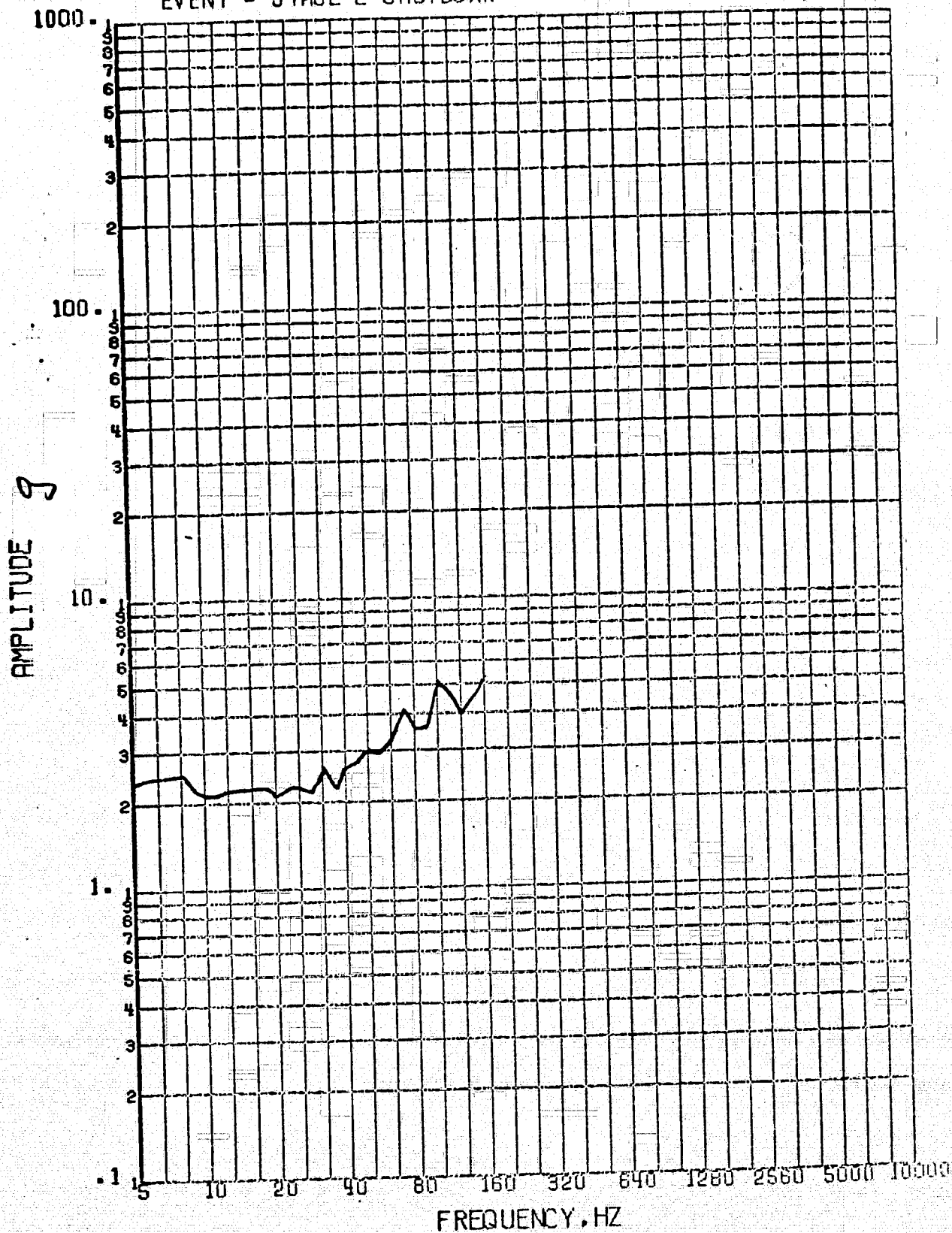
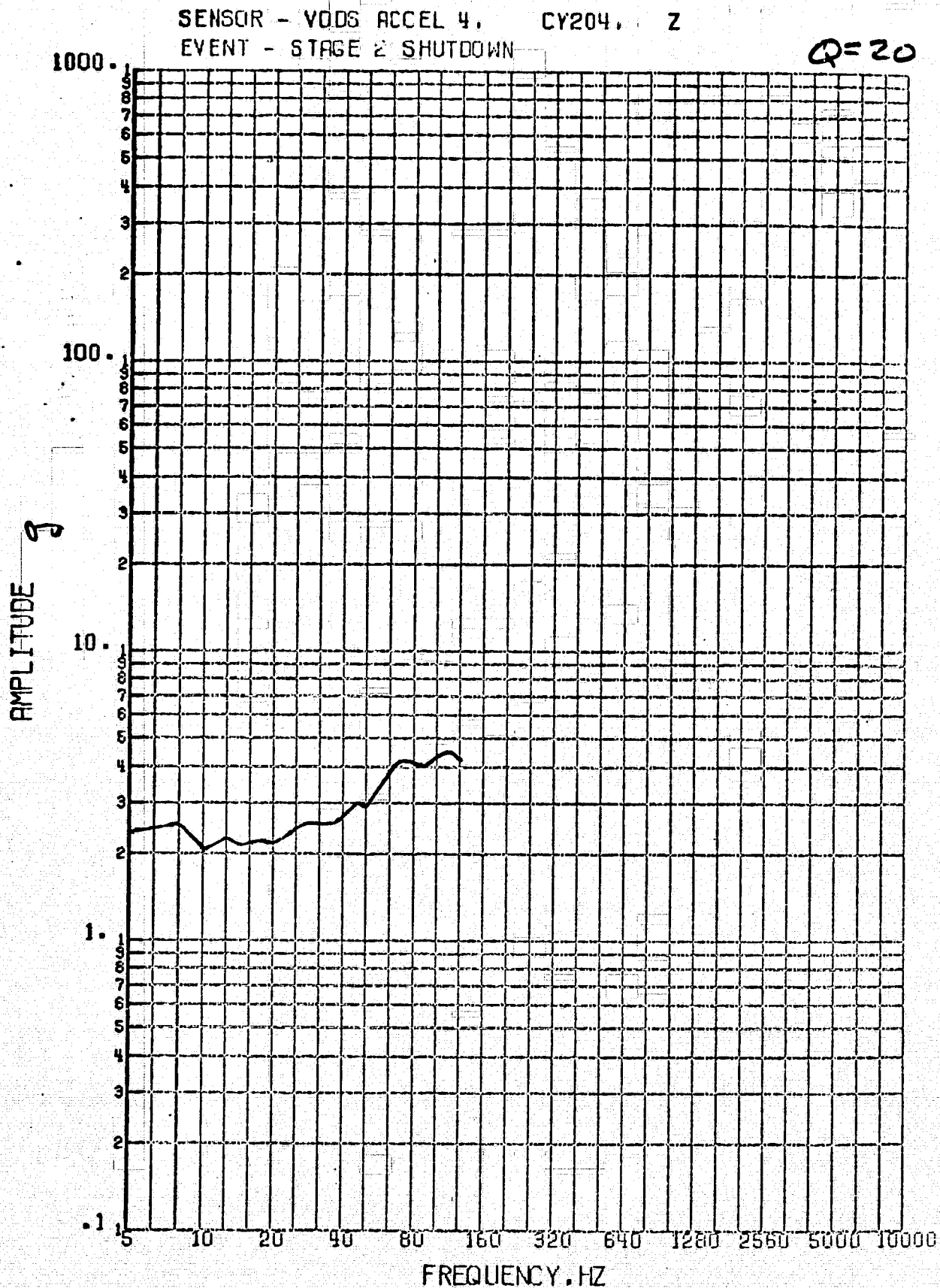


Figure 15c

2.118



2.119

Figure 15 d

SENSOR - VODS ACCEL 5. CY205. Y
EVENT - STAGE 2 SHUTDOWN

Q=20

AMPLITUDE g

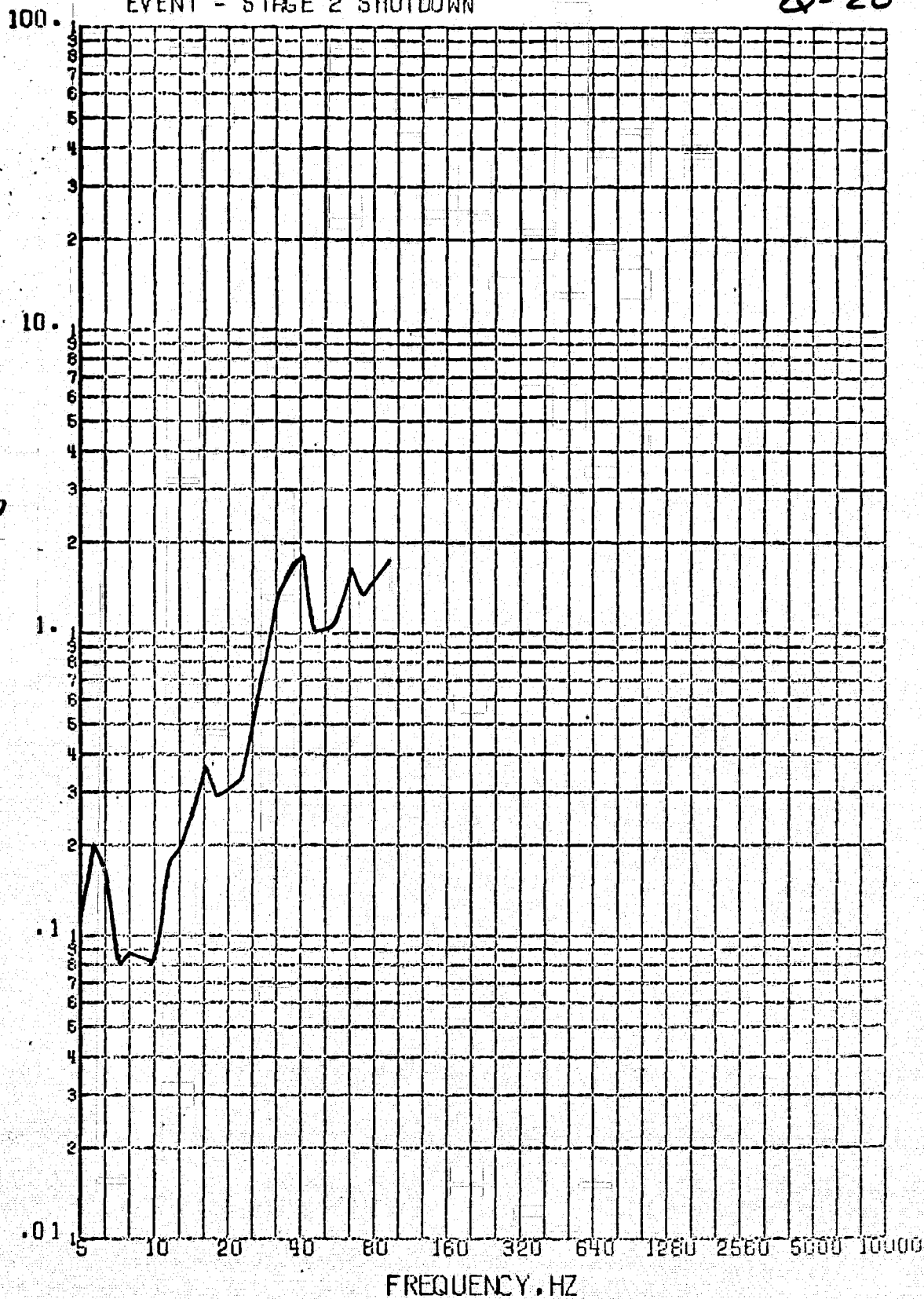


Figure 15 e

2.120

SENSOR - VDDS ACCEL 6, CY206, Y
EVENT - STAGE 2 SHUTDOWN

Q=20

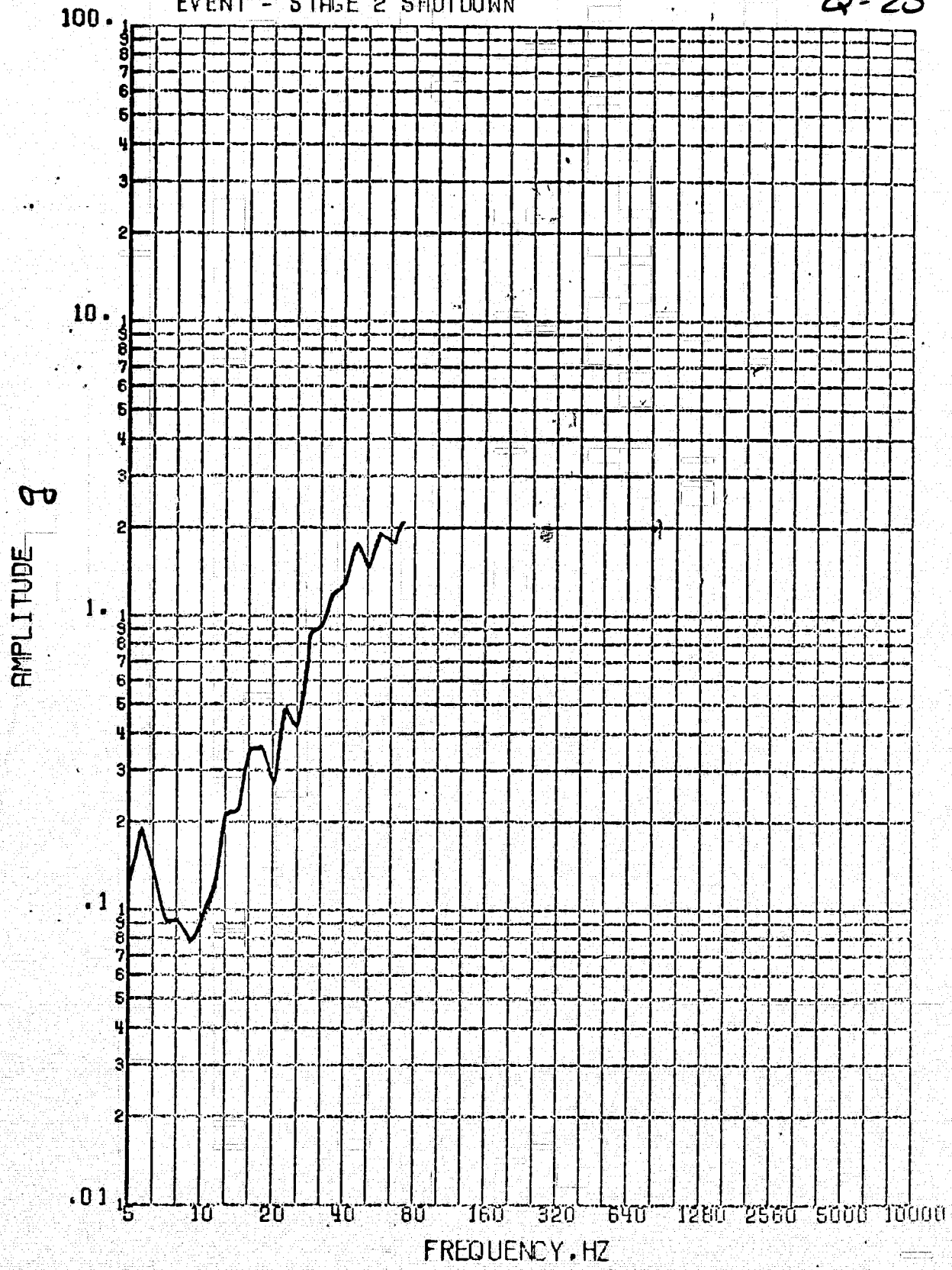


Figure 15 f -

SENSOR - VDDS ACCEL 7. CY207. X
EVENT - STAGE 2 SHUTDOWN

Q=20

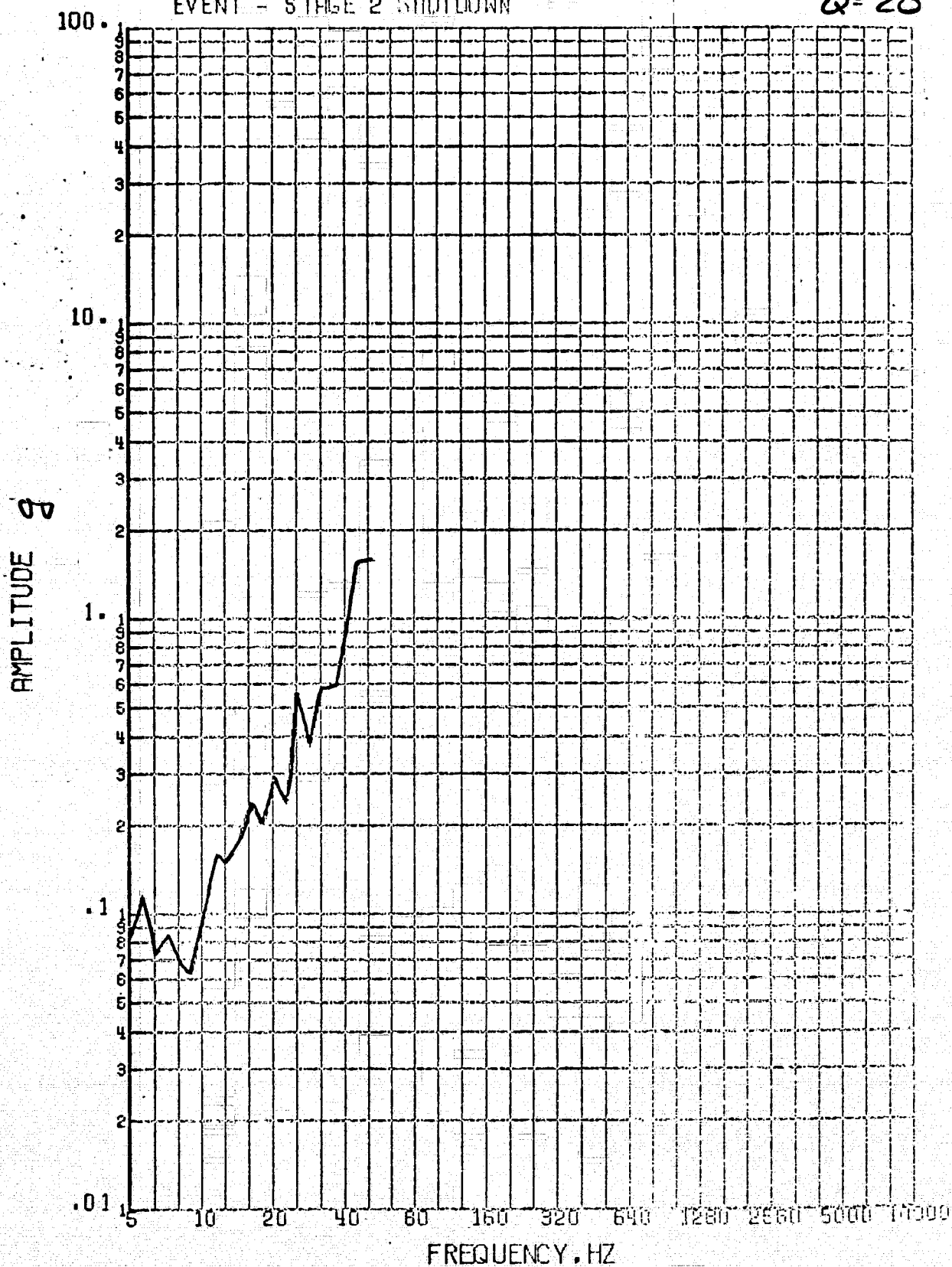


Figure 15 g

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2.122